

A B C
OF
VACUUM
POWER
BRAKES



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BENDIX ECLIPSE OF CANADA, LTD.
(Subsidiary Bendix Aviation Corp.)
WINDSOR, ONT.

BENDIX PRODUCTS DIVISION
OF BENDIX AVIATION CORPORATION
SOUTH BEND - - - INDIANA

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A B C
of
VACUUM POWER BRAKES



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Foreword

This manual is offered for basic training of students and apprentices in the fundamentals of automotive vacuum power braking—as exemplified in Bendix B-K products.

As the service industry enters the war period, it is confronted with the important task of maintaining existing transport vehicles at top efficiency; moreover, there is the urgent need of doing this with every possible economy of replacement parts and materials. The job is made more difficult by the fact that many new men are coming into the trade to take the place of more experienced men who have been called into military service or elsewhere in the war effort. In addition, great numbers of men in the military service must be trained from the ground up in the maintenance of motorized equipment as a part of the program of building the armed force necessary for Victory.

For these reasons, it is felt that an A B C book of this type is a timely contribution—that in addition to helping new men gain their first knowledge of vacuum power braking, it will aid the more experienced men in reviewing important principles.

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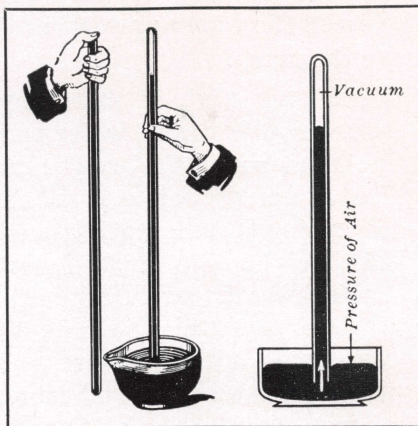
CONTENTS

PAGE

I	VACUUM AND ATMOSPHERIC PRESSURE	-	-	-				1
II	EARLY B-K HISTORY	-	-	-	-	-	-	13
III	PRESENT-DAY B-K	-	-	-	-	-	-	30
IV	OTHER B-K UNITS	-	-	-	-	-	-	105
V	DIAGRAMS OF TYPICAL B-K INSTALLATIONS	-	-					109
	ALPHABETICAL INDEX	-	-	-	-	-	-	128

ABC OF VACUUM POWER BRAKES

I VACUUM AND ATMOSPHERIC PRESSURE



Torricelli's experiment.

The first step in understanding the principles of vacuum power brakes is to gain a clear conception of the nature of vacuum and of atmospheric pressure.*

ATMOSPHERIC PRESSURE

The action of atmospheric pressure, which is the actuating force in vacuum power brakes, is demonstrated by an ordinary suction pump such as the old-fashioned "pitcher" pump often used to draw water out of a cistern or shallow well. Such a pump is provided with a piston which works in a cylinder and "draws" the water upward from the level beneath.

Discovery of Atmospheric Pressure

It is related that Galileo, a pioneer of modern science who lived in Italy during the early part of the seventeenth century, observed that the height to which a suction pump could lift water was limited to thirty-four feet. He did not succeed in explaining this limitation, but his friend and associate, Torricelli,

**Atmosphere*: The body of gases, commonly called air, that surrounds the earth.

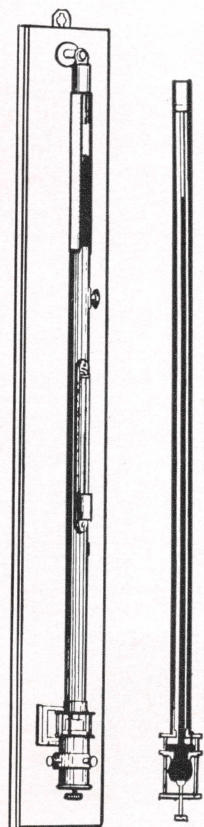
suggested that water rises in such a pump because atmospheric pressure bears upon the surface of the water. He believed that the function of the pump piston was simply to remove a part of the atmospheric pressure from above the water in the pump cylinder, after which external air pressure forced the water upward in the pipe leading to the pump.

He saw that, if that were the case, the pump could "draw" water no higher than the point at which the weight of the column of water exactly balanced outside air pressure. By a simple computation, he determined that the weight of a thirty-four foot column of water was about fifteen pounds per square inch of sectional area. That being the case, an atmospheric pressure of fifteen pounds per square inch was indicated.

He reasoned that it would be more feasible to prove his conclusions experimentally by using mercury instead of water. The atmospheric pressure should support a column of mercury weighing the same per square inch of sectional area as a thirty-four foot column of water, but due to the greater weight of mercury it would require only about $1/14$ the height.

In 1643, Torricelli performed an historic experiment to prove his theory. He used a long glass tube, which was closed at one end and open at the other. Into this tube he poured mercury, filling it completely. With thumb pressed over the open end, he inverted the mercury-filled tube over a pan of mercury so that the open end of the tube was beneath the level of the mercury in the pan.

*Early type
barometer following
Torricelli's prin-
cipal.*



Removing his thumb, Torricelli's anxious eyes watched the column of mercury fall, then rise again, and come to balance at a height *thirty inches* from the level in the pan. The atmospheric pressure was exactly balanced by the weight of this

column of mercury. Since a column of mercury thirty inches high weighs about fifteen pounds per square inch of sectional area, the atmospheric pressure indicated agreed with the action of suction pumps.

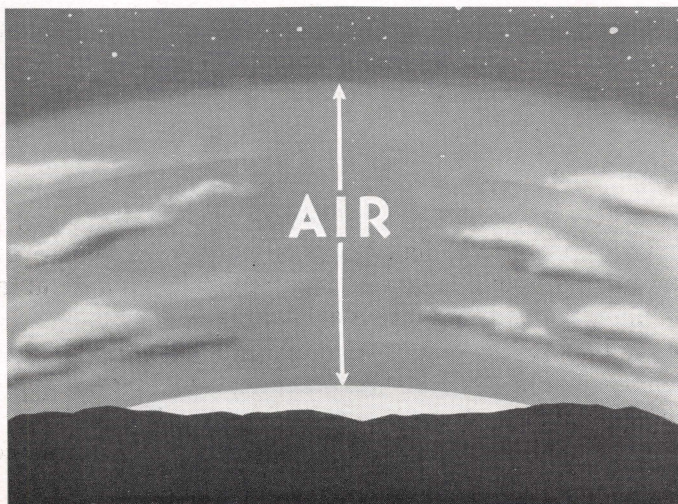
It was suggested that, if the principle held true, the mercury column would be shorter at heights above the earth since atmospheric pressure should decrease the nearer the top of the atmospheric layer was approached.

An enterprising experimenter, one M. Perrier, carried a device such as Torricelli used (later called a barometer) to the top of a mountain. There at a height of 4800 feet, he found that the air pressure would support only twenty-seven inches of mercury which exactly checked with Torricelli's theory of atmospheric pressure.

Later (1650) the invention of the air pump enabled experimenters to evacuate closed spaces and permitted proof beyond doubt of the existence of atmospheric air pressure and of the force that it is capable of exerting.

VACUUM

It may be said that we live at the bottom of an ocean of air—an atmospheric ocean that extends upward many miles. This mass of air has weight, just as the water in the ocean has



weight, and the weight of the atmosphere pressing downward produces "atmospheric pressure."

As we have seen, the pressure of the atmosphere at sea level is normally about fifteen pounds per square inch (14.7



"Any object . . . is subject to outside air pressure."

lbs. to be more exact) ; actually, this pressure varies somewhat, increasing and decreasing from day to day, and as we say, the barometer "rises" or "falls."

An Object at Sea Level

Any object at sea level—the open glass jar in the illustration for example—is normally subject to an outside air pressure of nearly fifteen pounds for each square inch of its surface—inside and outside; top, bottom and sides.

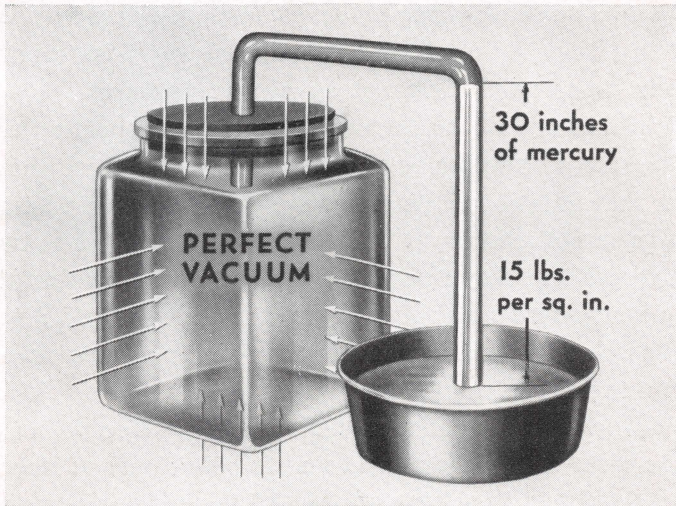
If we close this jar and pump the air from the inside, we say the space within the jar is a "vacuum." If all air is removed, the space is called a perfect vacuum because it is entirely free of air pressure. Meantime, note that the outside surfaces of the jar are still subject to the original outside air pressure.

Measuring Vacuum

Connecting such a vacuum to a pan of mercury by means of a glass tube, as shown below, the outside air pressure bearing down on the mercury in the pan forces mercury upward in the tube. In fact, we have duplicated here the elements of Torricelli's barometer; namely, a column of mercury with perfect vacuum above and atmospheric pressure below.

The space within the jar being a perfect vacuum, the mercury rises to a height exactly to balance atmospheric pressure (about thirty inches at sea level). On the other hand, if only a part of the air within the jar were removed and therefore only a "partial" vacuum existed, the height of the column of mercury would be correspondingly less. Thus the height of the column of mercury also is an indication of the degree of vacuum in the jar.

Instruments for measuring vacuum work on this principle, and vacuum is expressed in terms of "inches of mercury."



"Connecting a vacuum to a pan of mercury."

(Sometimes written, for example, as, 20" Hg; Hg is the chemical symbol for mercury.)

Since a thirty-inch column of mercury is balanced by an air pressure of about fifteen pounds, it is apparent that two inches

of mercury are equivalent to one pound difference of pressure (approximately) between the vacuum and outside air.*

The fact that it is this *difference of pressure* that is measured by the column of mercury is an important point to have clearly in mind; that is, a relatively high outside air pressure works against a lower inside pressure.

The Action of a Vacuum Cylinder

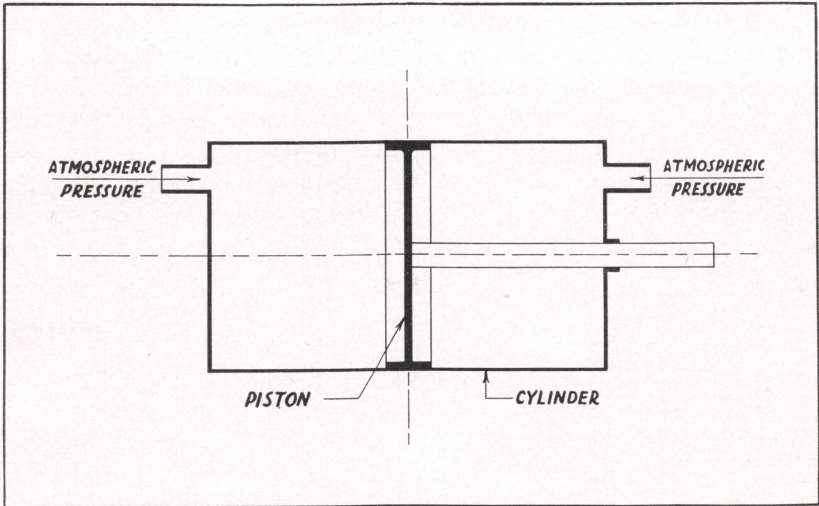
To clarify this principle further, let us analyze the action of vacuum and atmospheric pressure on a piston in a cylinder.

At the top of the page opposite, is shown a cylinder in which an air-tight piston has been fitted so that the piston is free to slide in the cylinder. Since both ends of the cylinder are open to atmospheric pressure, there is an air pressure of 14.7 pounds per square inch on each side of the piston. The piston, being subject to equal and opposite forces (balanced forces), is not moved in either direction, but remains at rest; we might say that it is "suspended" between equal air pressures.

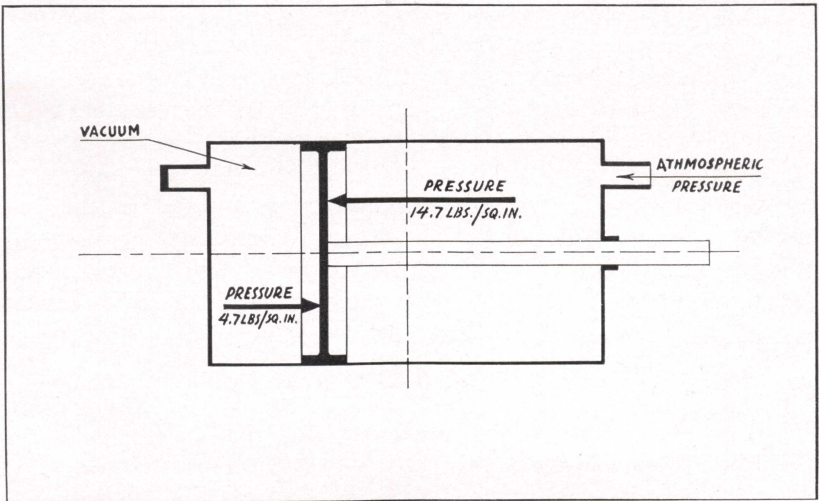
In the picture at the bottom of the page opposite, air has been evacuated from one side of the piston to reduce the pressure on that side to 4.7 pounds per square inch (a vacuum of twenty inches of mercury). The piston is still subject to two opposing forces, but they are no longer equal; one remains at 14.7 pounds per square inch, but the other is now only 4.7 pounds per square inch — a ten pound difference for each square inch of piston area.

Since the piston is being pushed in one direction with a force of 14.7 pounds per square inch, and is being pushed in the opposite direction with a force of only 4.7 pounds per square inch, it will be moved toward the low pressure side. The force exerted by the piston rod will be proportional to the pressure difference; that is, 10 pounds multiplied by the number of square inches of piston area.

*The assumption that one pound air pressure equals two inches of mercury is close enough for practical purposes and is used later in this book.



*A vacuum cylinder with both ends open to atmospheric pressure.
The piston is balanced or "suspended" between equal and
opposite pressures.*



*One end of the cylinder has been evacuated, unbalancing the
opposing forces, causing the piston to pull the piston
rod toward the low pressure side.*

To build up the same situation from a different approach, the picture at the top of the next page shows a piston balanced between equal and opposite pressures, but this time the opposing pressures are below atmospheric pressure; that is, they are partial vacuums. To maintain this condition, both ends of the cylinder are shown sealed against outside air pressure. In this case, we might say the piston is "suspended" between equal vacuums.

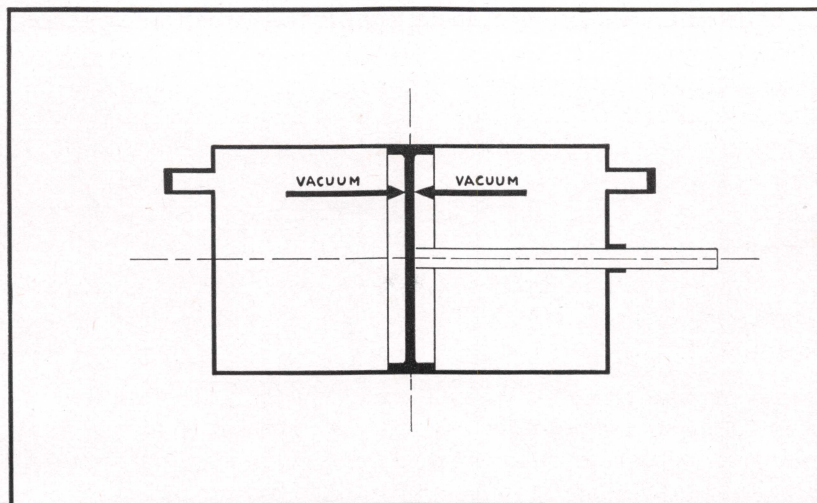
Now let us assume that we open one side of this vacuum suspended cylinder to outside air, as shown in the next picture, keeping the other side tightly sealed.

Here again we have unbalanced the opposing forces, but this time by *opening* one end of the cylinder to atmospheric pressure while the other remains under vacuum. The result, however, is exactly the same as in the first example; namely, one side of the piston is subject to a pressure ten pounds per square inch greater than the other side. It is apparent that the piston will move toward the low pressure side with a force of ten pounds for each square inch of piston area.

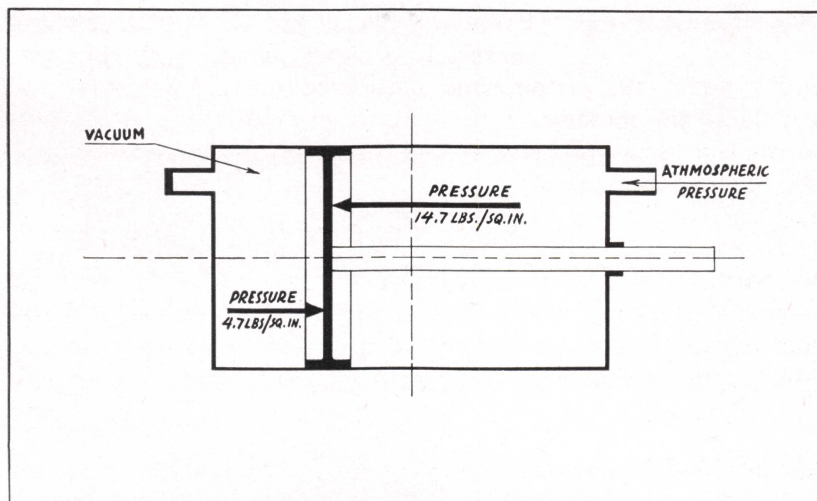
The Moving Force. From the foregoing, it is obviously not correct in a strict sense to say that vacuum "pulls" the piston, since it is atmospheric pressure that furnishes the moving force. The function of the vacuum is to lower the opposing force so that atmospheric pressure can do the work. In everyday language, however, it is customary to say that vacuum or "suction" pulls the piston, and in the following text where it serves the interest of clarity, the vacuum is spoken of as acting upon the piston instead of the more accurate expression. There is no harm in this loose use of terms and often there is a practical advantage, provided the correct underlying principle is understood.

Intake Manifold Vacuum

Due to the pumping action of the pistons in a gasoline engine as they draw air into the cylinders, a vacuum is created in the intake manifold. This is because the throttle valve partly obstructs the flow of incoming air so that air cannot enter the

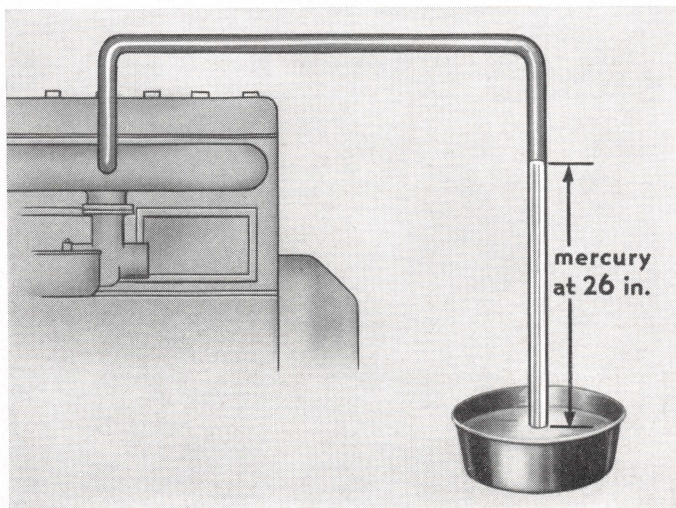


Piston balanced between opposite and equal pressure, but this time the pressures are partial vacuums.



Opposing forces have been unbalanced by opening one end of the cylinder to outside air, causing air pressure to force the piston toward the low pressure side.

manifold fast enough to keep up with the rapidly descending pistons. The result is that a certain amount of air must fill a space much larger than it would occupy under atmospheric conditions, producing reduced air pressure or partial vacuum.



" . . . a glass tube connects the intake manifold to a pan of mercury."

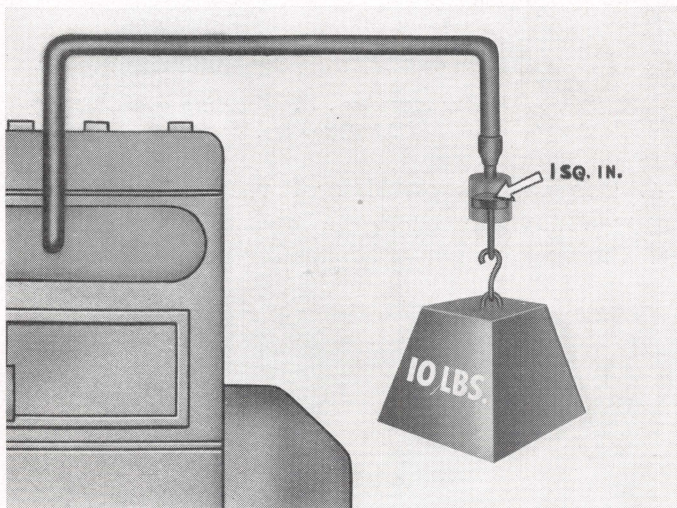
In this illustration, a glass tube similar to that previously shown, now connects the intake manifold of an engine to a pan of mercury. Outside air pressure acting against the surface of the mercury in the pan has forced mercury upward in the vertical tube to a height of twenty-six inches. This indicates that the difference in air pressure between the inside of the manifold and the outside air is equal to the weight of a twenty-six inch column of mercury (thirteen pounds per square inch). Such a vacuum of twenty-six inches of mercury may exist in the intake manifold of an engine under favorable conditions. To adopt a uniform standard, however, a manifold vacuum of twenty inches of mercury is assumed in vacuum power brake practice.

HARNESSING "VACUUM POWER"

To illustrate the power available from this intake manifold vacuum, assume that a small cylinder with a piston exactly one square inch in area is connected to the intake manifold of an engine, as shown in the picture below.

Atmospheric air pressure exerted upward against the piston is shown supporting a ten-pound weight.

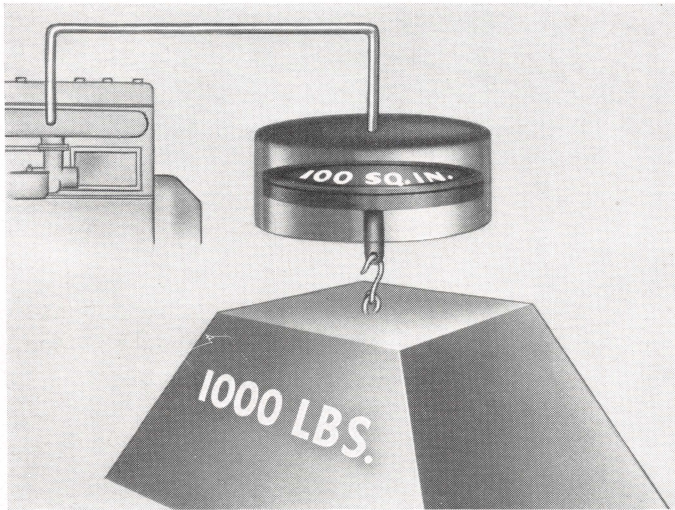
Explanation: A vacuum of 20" of mercury is equivalent to a pressure difference of ten pounds per square inch, therefore, the lift would be ten pounds on a piston of one square inch area.



"Atmospheric pressure . . . supporting a ten-pound weight."

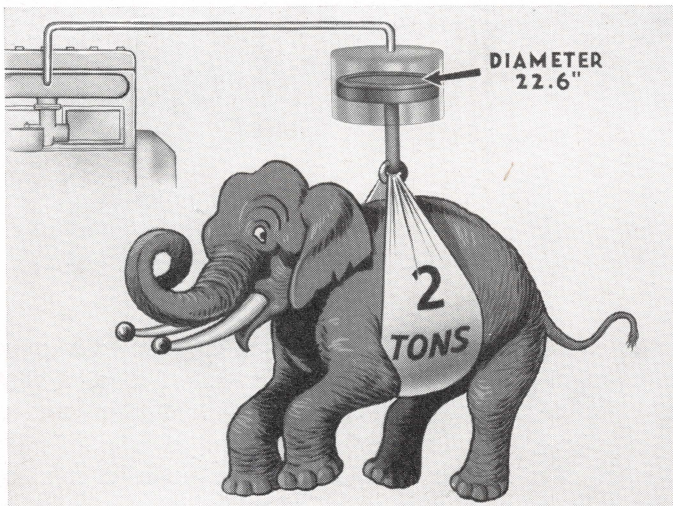
By increasing the area of the piston, correspondingly greater lift or working force may be obtained from the twenty-inch vacuum; that is, a piston of two square inches in area would support a twenty-pound weight ($2 \times 10 \text{ lbs.} = 20 \text{ lbs.}$).

In the illustration on the next page, a much larger cylinder has been substituted, having a piston of 100 square inches in area (about 11.3 inches in diameter). Such a piston would be capable of supporting a weight of 1000 pounds.



"... a larger cylinder ... supporting a weight of 1000 pounds."

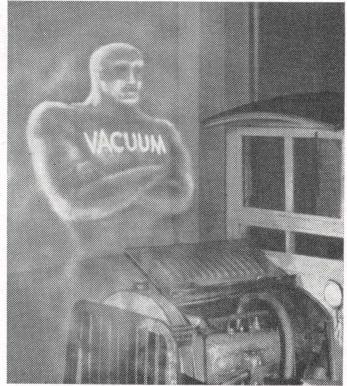
With this basic knowledge of vacuum and atmospheric pressure, we may proceed to the practical application of these principles in vacuum power brakes for automotive vehicles.



Illustrating the power of vacuum: A manifold vacuum of twenty inches of mercury is supporting a two-ton elephant!

II EARLY B-K HISTORY

Early in the development of motor trucks it became apparent that some power was necessary for brake application other than the unaided physical force of the driver's foot. For a given stopping rate, braking power increases directly with the load, and as the square of the speed. This means that doubling the load requires double the stopping power; whereas, doubling the speed requires four times the stopping power; doubling both load and speed requires eight times the stopping power.



Increasing leverage to allow the driver to exert greater braking power was limited by the feasible length of levers and the distance the driver's foot could conveniently travel.

The Problem of Added Braking Power

The need of power braking having been thoroughly established, the question arose of what source of power could be used and the method for applying that power. Early experimenters worked with devices based on various principles. One system used oil from a high pressure pump driven by the engine; another sought to utilize torque from a friction unit on the vehicle propeller shaft.

James T. Dickson



James T. Dickson.

Among the pioneers of power braking was an engineer named James T. Dickson who prior to 1913 had been working on the problem in Los Angeles, California.

Dickson greatly questioned whether any source of power that had been suggested, was entirely suitable for the peculiar conditions of automotive vehicles.

His analysis pointed out that the ideal system for applying motor vehicle brakes should be:

1. Simple in mechanical construction to avoid maintenance problems and to insure dependability.
2. Compact in form and without the need of adding complicated units to the vehicle.
3. Moderate in original cost.
4. Safe and dependable in operation.

At this point, Dickson emphasized the principle that whatever medium was used, the original braking system of the vehicle must remain intact. In this way, the original braking system could serve as an emergency means of stopping the vehicle should the power system fail due to accidental damage or other cause.

He pointed out that motor trucks, unlike railway trains, operate on irregular road surfaces and are subject to severe road shocks; that they must make frequent stops, travel on irregular schedules and otherwise meet conditions of severe service with a minimum opportunity for inspection and for maintenance service.

With keen insight, Dickson reasoned that the logical answer was to utilize the vacuum in the intake manifold. His practical mind quickly grasped the advantages of using a ready-made working air pressure of ten to thirteen pounds per square inch, which was available from the intake manifold vacuum.

As an engineer, he realized that this pressure could be multiplied into any working force needed for full brake application by simply increasing the piston area; that is, by giving the available air pressure more square inches to work against.

Fired with the conviction that in vacuum power he had at last found the right medium, he started to make a vacuum power brake for an old Reo touring car. First he determined the brake rod pull in pounds that was necessary to get full brake application on this vehicle. Then he computed the size cylinder and piston that would be necessary to get this brake rod pull from the intake manifold vacuum.

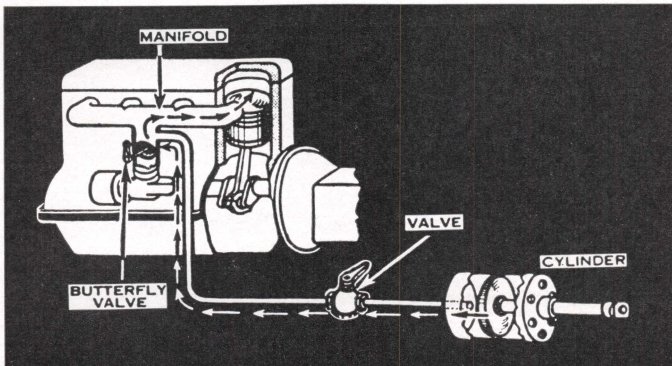


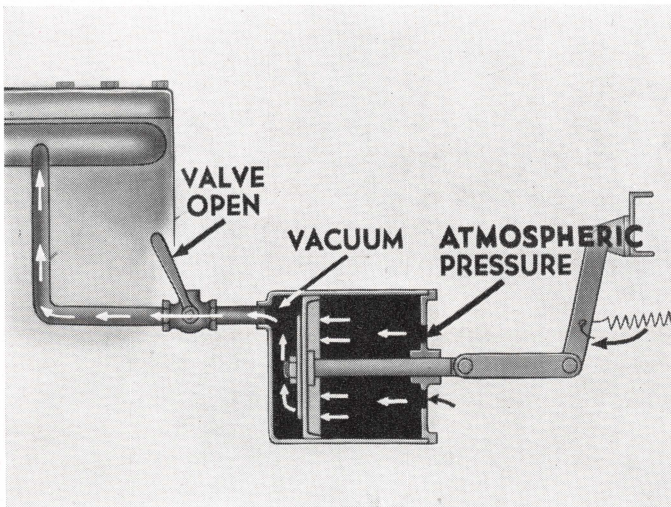
Diagram of original system as installed by Dickson.

He made a cylinder of the indicated size, and in this cylinder he fitted an air-tight piston with a suitable piston rod and guide.

With eager hands, Dickson attached this "contraption" to the car so that the pull of the piston would operate the brakes. In doing this, he made sure that the installation did not interfere with the normal operation of the braking system. In other words, he followed his own doctrine of leaving the original braking system intact.

A hose from the cylinder was connected to the intake manifold of the engine. In this vacuum line he installed an ordinary three-way hand-operated valve which he purchased as a standard fitting at a hardware store. This valve gave hand control of the brakes as follows:

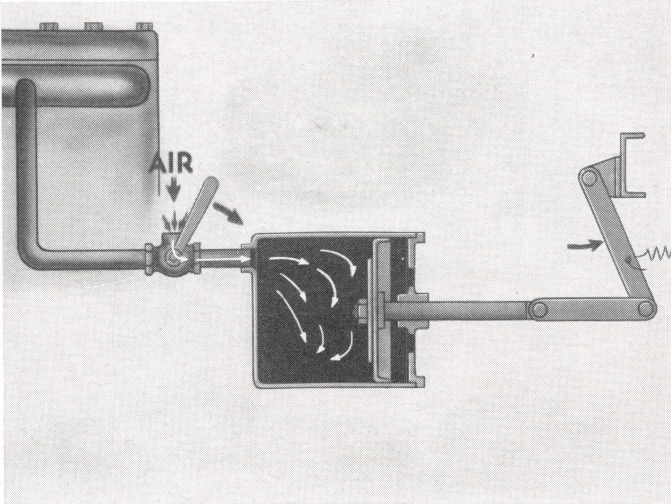
1. *Applied.* In the applied position the valve connected the cylinder to the vacuum in the intake



Brakes applied.

manifold; with air removed from in front of the piston, atmospheric pressure on the other side of the piston forced the piston into the cylinder and applied the brakes.

2. *Released.* In the released position the valve closed the passage to the intake manifold and opened a port which allowed atmospheric pressure to enter the evacuated end of the cylinder. This restored

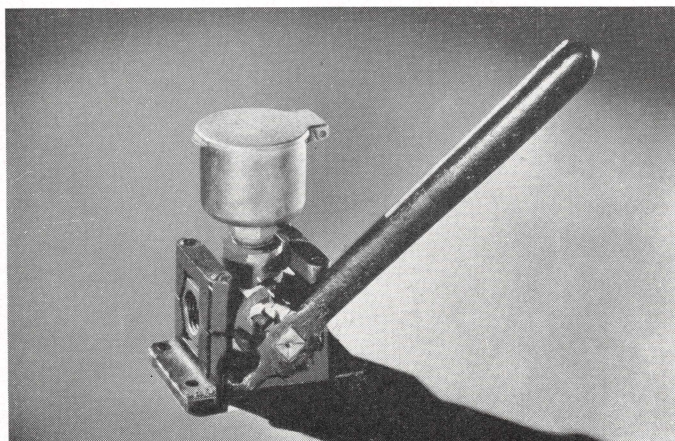


Brakes released.

balanced atmospheric pressures on either side of the piston and allowed the brakes to return to released position.

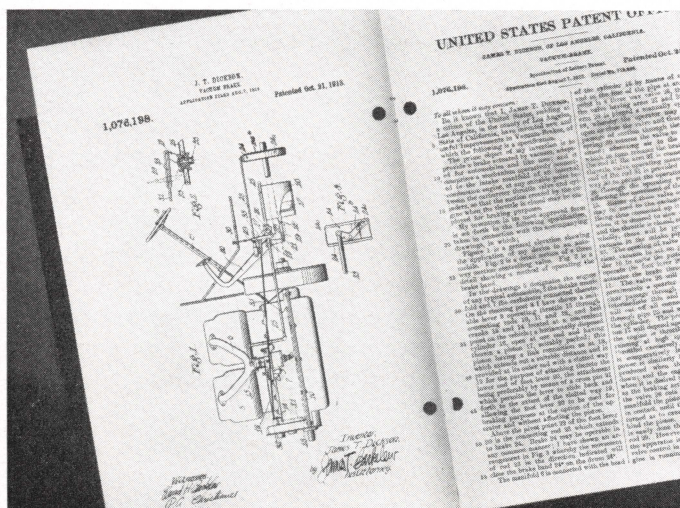
Since in this first installation the control valve was hand operated, there were two independent means of brake application: (1) hand operation of the power braking system; (2) foot operation of the original foot-power braking system. Of course, there was the third possibility of operating the two systems in combination, if the operator were skillfull enough to coordinate the use of the hand valve with the foot pedal.

Although this first vacuum power brake was a crude beginning and imperfect in results, it clearly proved Dickson's contention that by utilizing intake manifold vacuum, a simple, compact and inexpensive power brake system could be made; moreover, that such a system would leave the original physical braking system free to operate either in conjunction with the power system or separately as an emergency provision.



From a photograph of the original Dickson valve. The oil cup at the top is an improvised air cleaner.

On October 21, 1913, Dickson was granted a patent covering the principles of this device. This marked the official beginning of the use of vacuum from the intake manifold for the application of motor vehicle brakes.



From a photograph of the original patent granted Dickson.

Fisher and Allison

While Dickson was doing these things in California, two engineers, who later became famous as automotive pioneers, were working on the same problem in Indianapolis, Indiana; these were Carl Fisher and James Allison. They, too, had experimented with various types of power brakes for automotive use and like Dickson they had concluded that vacuum from the intake manifold was the logical answer. At this point they ran into Dickson's patent rights, but were so firm in their faith in the vacuum principle that they arranged to continue their work under license privileges from that patent.

Under Fisher and Allison a number of improvements were worked out including the development of the follow-up principle for the control valve.

The main objection to the earlier type valve was the tendency for the power brakes either to be *ON* full force, or *OFF*—there was no accurate graduation of brake control.

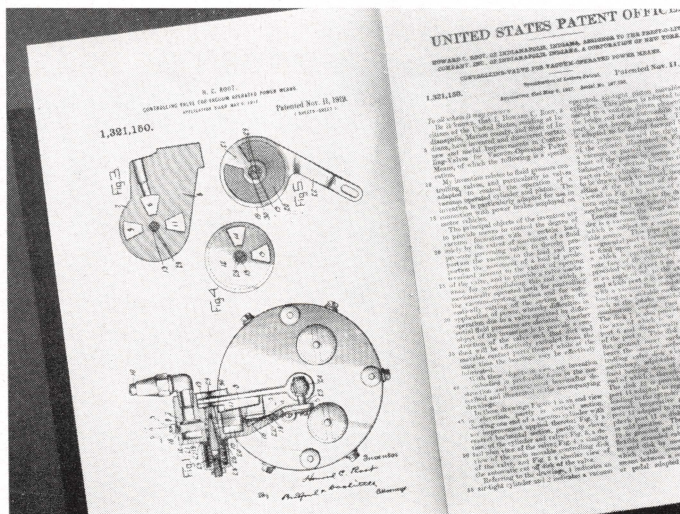
H. C. Root

An engineer employed by Fisher and Allison at Indianapolis named H. C. Root, designed a valve intended to provide the desired graduation of control. To do this, Root utilized what became known as the follow-up principle, which was the beginning that ultimately led to control valves as we have them today. This follow-up valve was so arranged that, as it was opened and the brakes came on, the action of the brake levers, pulled by the vacuum cylinder, tended to close the valve.

In this way, if the brake pedal was depressed half way, vacuum applied the brake to half power; similarly, for all degrees of brake application, the power system followed the brake pedal. This allowed the driver to control the *degree* of brake application by the *position* of the pedal.

The follow-up principle* was a basic contribution to vacuum power brakes and was subsequently covered by a patent dated November 11, 1919.

*Further details of present-day follow-up type control valves are given later.



From a photograph of the original Root patent covering the follow-up principle in the control valve.

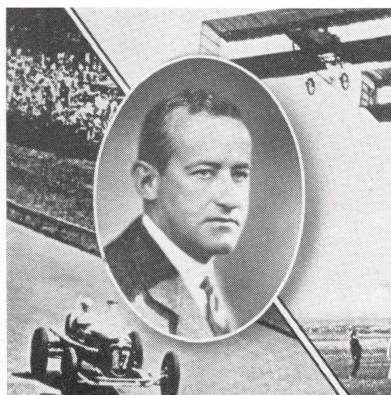
Bragg and Kliesrath

At about this stage of development Caleb S. Bragg, a man who had pioneered in automobile and airplane engineering as a sportsman and independent experimenter, became interested in the Fisher-Allison experiments, and in 1922 purchased their patent rights and models.

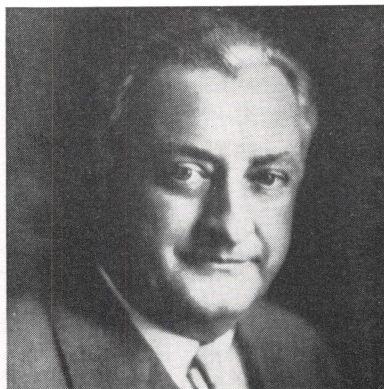
Mr. Bragg invited Victor W. Kliesrath to become associated with the project as an engineer in further development of vacuum power braking. Their first experimental shop was in Mr. Bragg's airplane hangar located at Port Washington, Long Island. Eventually they formed the Bragg-Kliesrath Corporation and located in Long Island City, New York.

In the hands of Bragg and Kliesrath the vacuum brake underwent a period of rapid improvement. It first appeared on the market in 1925 under the trade-name of the B-K (Bragg-Kliesrath) Power Brake, and soon became recognized as a practical solution to the automotive power brake problem.

Prior to commercial introduction, however, there was the need of detailed refinement and of exhaustive practical tests.



Caleb S. Bragg



Victor W. Klierath

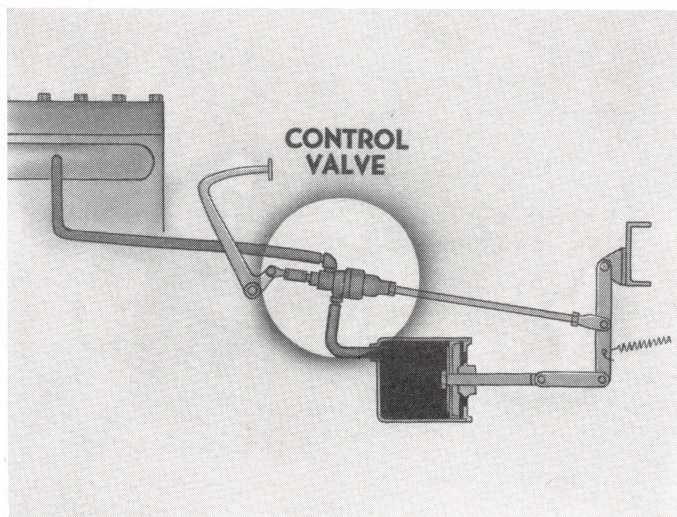
Location of the Control Valve

One of the interesting details of this early work was the matter of locating the control valve so that it would be operated by the foot pedal and also automatically give a combination of physical and power actuation. From an early date, Dickson's hand-operated valve had been discarded in favor of a similar device linked to the brake pedal so that action of the driver's foot operated the valve. Later, the Root type follow-up valve was similarly located. In these systems, however, the valve was always attached to the chassis, with connecting linkage to the foot pedal of the vehicle.

The need of improvement on this plan had long been apparent and a great deal of thought had been given the subject. As in the history of many inventions, the solution when found was quite simple and obvious, so much so, in fact, that it is amazing how it could have been overlooked by the numerous competent experimenters who worked for years on the problem.

It occurred to Bragg and Klierath to cut out a section of the brake rod running from the pedal, and to insert the control valve in place of the removed section of the brake rod. With the valve thus "suspended" as a part of the control rod, the braking system became an ideal combination of physical operation and power operation, with all the superior graduated control of the follow-up type valve. Any desired ratio between

physical and power actuation could be obtained. The system could be designed either to require normal physical effort on the pedal, aided and supplemented by the power system, or the power could be increased with a corresponding decrease in the physical effort needed. Then, should the power system fail, the operating valve would simply serve as a mechanical link for transmitting the physical force from the driver's foot to the brake linkage, thus automatically changing the system back to full physical operation. This method of mounting the control valve became the subject of a patent, and of course has since then been the accepted practice.



The control valve mounted as a section of the brake rod.

Two other important contributions made by Bragg-Kliesrath were (1) the vacuum suspended system, and (2) reactionary control.

Details of these as applied in modern B-K units will be taken up later, but for the present the following gives the principles as part of early B-K development.

The Vacuum Suspended System

In the original systems, opening the cylinder to vacuum drew the air from the cylinder and allowed outside air pressure to apply the brakes.

On large installations, there was some disadvantage in the need of first exhausting the air from the vacuum line and cylinder to apply the brakes. The larger cylinder and the longer lines contained a considerable volume of air. The time required to exhaust this air produced a lag in brake operation; moreover, a large volume of air suddenly entering the intake manifold interfered appreciably with engine operation.

It was realized that elimination of these conditions would further improve the system for larger vehicles, on which, of course, the need for power braking was most urgent.

The story of the invention of the vacuum suspended system as told years later by a man who was there as an experimental mechanic, and who, by the way, is still in the B-K organization, goes this way:

“It happened one night in the old airplane hangar at Port Washington, which in those days we used as a work shop.

“We had been working for several days—and nights too, with a big truck on which we had installed the largest power cylinder that had been used up to that time.

“‘Caley’ Bragg was there, perched high on an old wooden box in one corner of the shop. He had been smoldering along in a brown study and I’m telling you he was in no fit humor to be trifled with; this particular job had been a real headache with no plausible answer in sight.

“The trouble was the power cylinder was so large that every time you stepped on the brake it dumped about a bucketful of air into the intake manifold and stopped the engine. We had tried just about everything—even including a gasoline jet in the manifold fitting to squirt a little gasoline in with the air! Nothing seemed to work and as ‘Caley’ glared down upon us it made us a bit nervous, just like it was our fault that we had struck a snag! It looked like we had reached a limit of size for power cylinders; and of course,

it was plain that the big jobs needed power brakes most of all.

“Then it happened. ‘Bang!’ like that—sudden enough and loud enough to scare a nervous bunch out of their wits. No, the truck didn’t blow up,



The first B-K experimental shop.

but ‘Caley’ did! That is, he popped off of that box, fairly exploding with the force of a big idea that had hit him.

“ ‘Say,’ he said, ‘what in the blazes is the matter with you fellows? Why this thing is as simple as A B C! Listen, now. Fix that cylinder so both ends will hold vacuum. Then run a vacuum line to the back as well as to the front of the cylinder. That way you’ll have vacuum on both sides of the piston, and with this balanced pressure the brakes will be off. Rig the control valve up so when we push the pedal, it will dump air into one end of the *cylinder* instead of into the *manifold*. That will apply the brakes and apply them fast!’

"It was so simple everyone there got the idea like turning on a light. We went to work and as the shop windows began to show gray with the light of morning, we had the first vacuum suspended system ready for test."

The solution proved to be as effective as it was simple and ingenious. The new system did not affect engine operation, and had the important added advantage of speeding up brake operation; the cylinder and lines acted as a vacuum reservoir in which potential brake power was always poised ready for instant use.

The term "vacuum suspended" system came from the fact that in the released position, the power cylinder piston was balanced or suspended between equal vacuums. For distinc-



*"'Caley' Bragg was there, perched on an old wooden box."
Illustration from the B-K sound slidefilm
"Products of Progress."*

tion, the original plan was called the atmospheric suspended system because in the released position, the piston was balanced or "suspended" between equal atmospheric pressures.

Reactionary Control

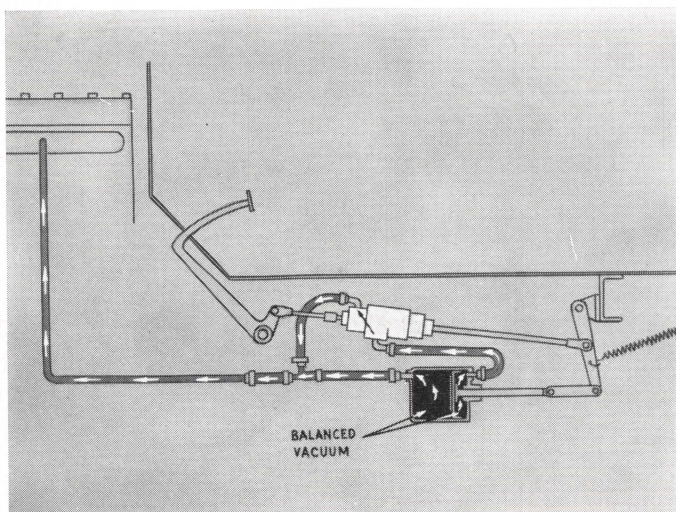
In the story of early B-K development, there remains one more important chapter. We have pointed out that the follow-

up valve provided *POSITION* control; that is, the brakes were applied in proportion to the distance the pedal was moved from the released position.

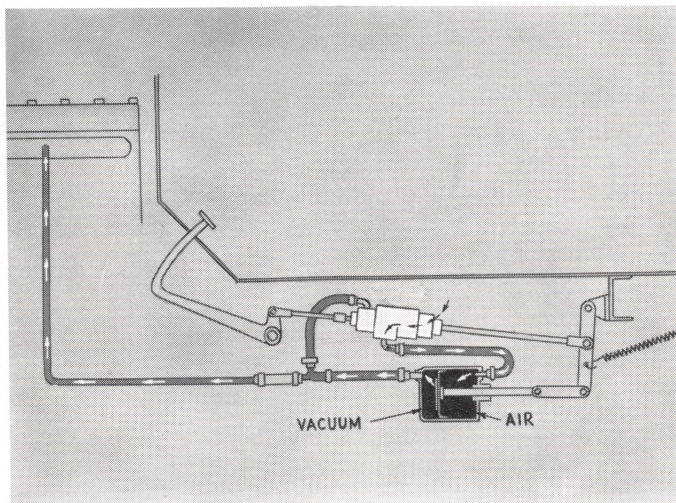
While this was a vast improvement over the original valve, still it is a fact that drivers instinctively control brakes not only by the distance the foot moves the pedal, but by the force or physical "push" that is exerted.

It was realized that this same combination of *pressure* and *position* control on power brakes would add vastly to ease of operation and accuracy of control. The result was accomplished by adding a diaphragm to the control valve which caused the valve to resist further opening in exact proportion to the degree of brake application. It gave the driver "feel" in that the harder he pushed the more braking force he applied; conversely a light push on the pedal gave a light brake application. This improvement was an immediate success because:

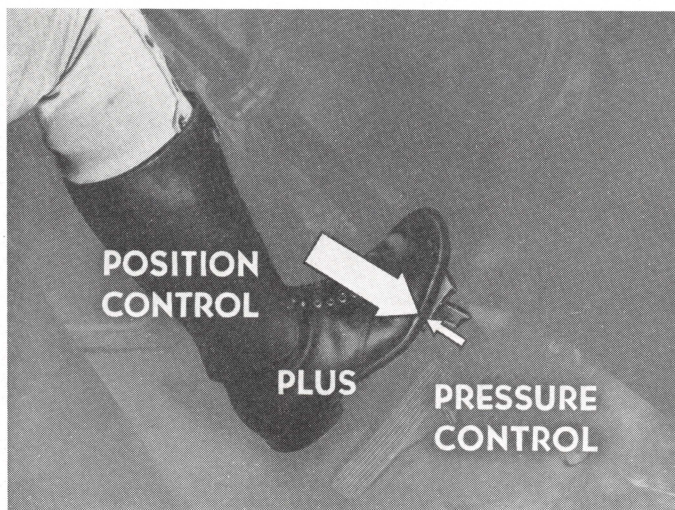
- It conformed to instinctive pedal action.
- It tended to prevent over-braking in emergencies.
- The driver sensed the rate of braking and therefore compensated instinctively for the difference in force required to apply brakes on a lightly loaded vehicle, and on one carrying full load or, possibly, overload.
- It allowed the driver to graduate brake application to stay under the skid point of the wheels.
- It gave better control over erratic brakes.
- It permitted the use of larger power cylinders without danger of lock-wheel stops when the same vehicle was running light or empty.
- It reduced cost per mile on tires and brake lining, by reducing wheel sliding and over-braking.



The vacuum suspended system with brakes off. The power cylinder piston is subject to balanced vacuum, therefore the brakes are released.



The vacuum suspended system with brakes applied. Air has been admitted to the control side of the cylinder, forcing the piston into the cylinder and applying the brakes.



The effect of reactionary control.

Since this principle applied a *counter pressure* against the driver's foot pressure, or met the driver's foot-action with an opposing "reaction," it became known as the "reactionary" principle.

Internal Valve Cylinders

Reactionary control is also obtained in present-day equipment by obtaining the reactionary force mechanically from external linkage instead of from a diaphragm in the control valve. The result in better brake control is exactly the same; the difference is simply in the manner of obtaining that result. (Further details later.)

The Move to Bendix

The year 1930 marked another important step in the progress of B-K. In the spring of that year the Bragg-Kliesrath Company moved their equipment, patents, and veteran key personnel into the plant of Bendix Products Corporation.

The great facilities of the Bendix Corporation, (since known as the Bendix Products Division of Bendix Aviation Corporation) made possible continued development of B-K.

An important result of this continued expansion has been the growth of a nation-wide service organization consisting of factory-authorized distributors and dealers. These service representatives are available to vehicle operators throughout the country, not only as sources of repair parts, but as factory-trained consultants on vacuum power brake maintenance service.

Particular emphasis is placed upon periodical inspection and reconditioning of units on the preventive service basis. It is, of course, important to maintain highway transport vehicles so as to avoid road trouble rather than to wait for reports from drivers, or for actual road delays to indicate the need of maintenance work. From the angle of preventive maintenance especially, Bendix B-K distributors offer their services to all users of vacuum power brakes to assist in keeping vehicles operating on schedule and with minimum cost for repair work.



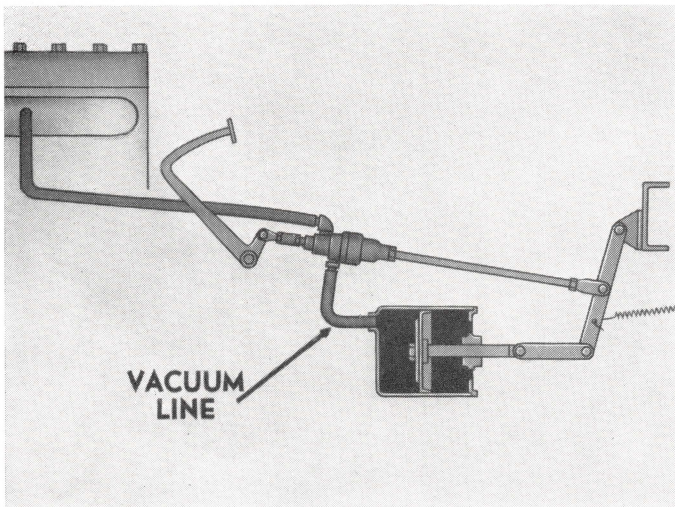
III PRESENT-DAY B-K

TRUCK SYSTEM, ATMOSPHERIC SUSPENDED

Proceeding to a more specific study of present-day B-K systems and units, let us start with the simplest type installation; namely, an atmospheric suspended system on a truck.

Reviewing briefly the original device installed by Dickson, we have these basic units:

1. A power cylinder.
2. A control valve.
3. Suitable hose connections between the units and to the intake manifold.



Basic system with modern type control valve.

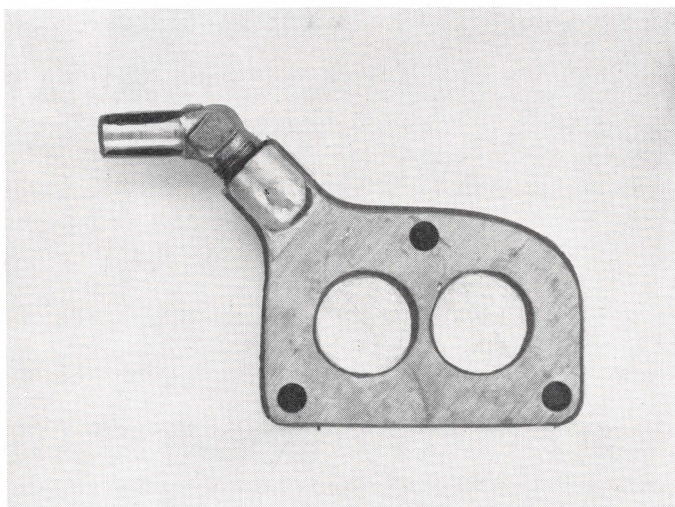
In this picture we show these same units, diagrammatically, in their present-day form. A follow-up type control valve is mounted as a section of the brake rod; flexible hoses connect the control valve to the cylinder on one side, and to the manifold on the other. When the valve is moved into the "on" position by action of the brake pedal, the cylinder is connected to manifold vacuum and the brakes are applied. The brake rod

pull necessary to open the valve is automatically added to the pull from the power cylinder and therefore, added to the force of brake application.

In addition, should there be no vacuum due to accidental breakage of lines or other cause, the control valve then acts simply as a link for transmitting the foot-power of the driver to the brake rod* exactly the same as if there were no power brake system. This is the emergency feature previously emphasized—"leaving the normal braking system intact."

Connection to the Manifold

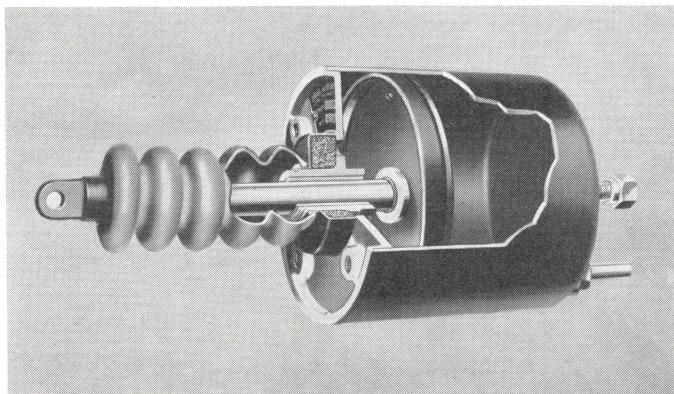
The vacuum line is connected to the intake manifold near the center of the manifold rather than at either end because vacuum conditions at this point are more favorable. Instead of drilling and tapping the manifold, a good practice that is frequently followed is to use a special insert between the carburetor and manifold flanges called a "sandwich." This plate is drilled and tapped for a fitting which takes vacuum from the most favorable position, that is, close to the throttle valve.



"Sandwich" fitting for the vacuum connection.

*For simplicity, mechanically actuated braking systems are usually assumed in explanations; the difference in application to hydraulically actuated braking systems is obvious.

Power Cylinder



*Atmospheric suspended power cylinder
(B-K type E Cylinder).*

This sectional view of a typical atmospheric suspended power cylinder shows the internal construction. The piston rod end or rear* of the cylinder is open to atmospheric pressure, whereas the opposite end provides means of connection to the vacuum line.

Air entering the open end (rear) of the cylinder is filtered through a thickness of curled hair to prevent dust and dirt from entering the cylinder. Such foreign matter, if allowed to enter the unit, would cause friction and rapid wear. The arrangement shown is called an integral air cleaner since the air cleaner is built-in as a part of the cylinder unit. Some cylinders and other B-K units do not have the air cleaner built-in, but instead have a threaded opening for the air inlet. Such units require separate air cleaners which may either be attached direct or remotely located for better dust protection.

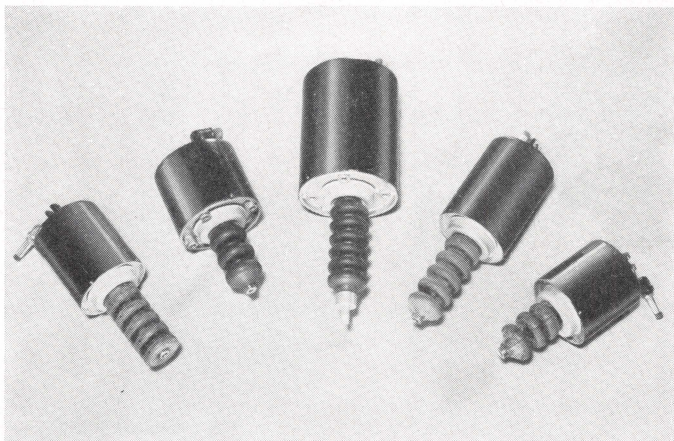
The piston is provided with a leather cup with the lip extending away from the vacuum side to insure an air-tight fit against the cylinder wall.

Lubrication is provided from time to time by putting a small quantity of special lubricating oil into the cylinder. Ordinary

*For uniformity in terms, the piston rod end of a cylinder is always called the rear, regardless of the position of the cylinder in the chassis.

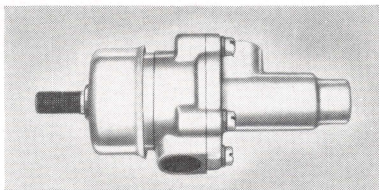
lubricants should not be used in vacuum cylinders due to their effect on the leather cup.*

The piston rod slides through a bearing in the cylinder end-plate. An accordion-folding rubber boot serves to protect the exposed part of the piston rod from outside dirt.

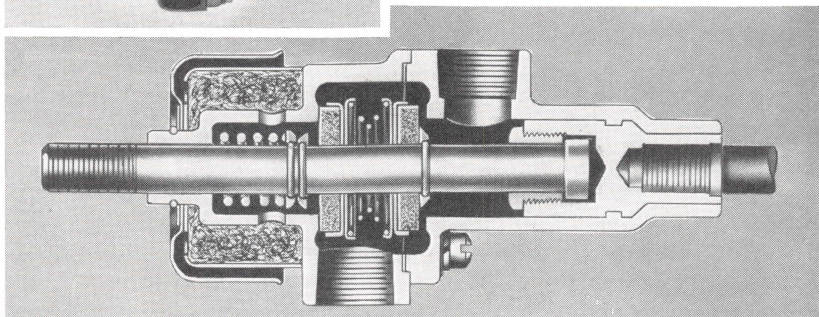


Typical B-K cylinders for atmospheric suspended systems.

Control Valve

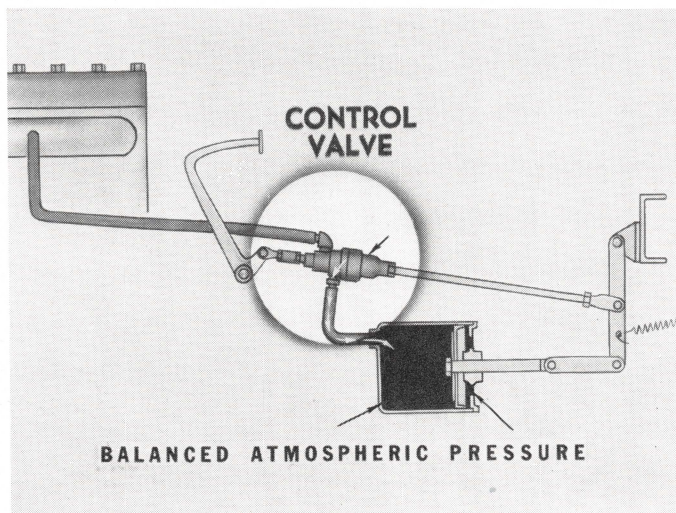


Outside and sectional views of atmospheric suspended control valve (B-K type XA Valve.)



*Bendix Vacuum Cylinder Oil is especially recommended for the purpose.

The foregoing illustrations show an atmospheric suspended control valve (B-K type XA Valve). The inside construction and operating principles of a similar valve will be described in detail later under vacuum suspended systems. Meantime,



An atmospheric suspended system with brakes released.

valve action will be discussed from the viewpoint of what it does rather than how it does it.

Released. In the diagram above, the brake pedal is shown in released position; therefore, there is no "pull" (tension) on the brake rod or on the valve assembly. Under this condition, the valve is in the "off" position; that is, vacuum is shut off from the power cylinder and at the same time a passage is opened to outside air. This places both sides of the piston under balanced atmospheric pressures and no pull is exerted.

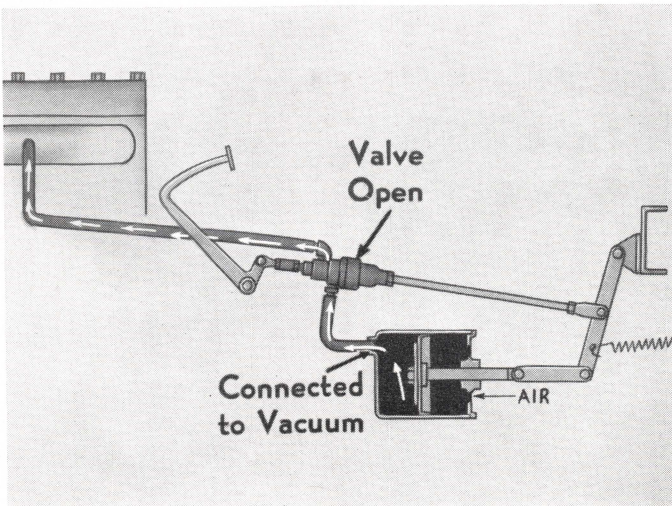
Applied. In the next diagram, the brake pedal has been depressed to approximately the half-applied position. The first action of the driver's foot was to exert a pull on the brake rod and control valve. When this tension reached a predetermined amount, it overcame spring pressure within the valve, closing the air passage and connecting the cylinder to

vacuum. This unbalanced the air pressures on the piston, allowing atmospheric pressure to apply the brakes.

Holding. Assume that at this half-way point the driver held the brake pedal without further application and without release. The power cylinder would pull the brake lever and in so doing would push the brake rod toward the valve. This movement would continue until the valve was pushed into the "holding" position. In the holding position, the power cylinder is cut off from further vacuum and at the same time it remains sealed from outside air. The result is to hold the existing degree of vacuum and thus to hold the brakes partly applied in obedience to the position of the brake pedal.

Further movement of the brake pedal in the applied direction would again open the vacuum valve causing brake application as above.

Release of the brake pedal takes all tension off the brake rod and off the control valve. This allows the valve to return



An atmospheric suspended system with brakes applied.

to released position, closing the vacuum passage and again opening the cylinder to outside air pressure. This restores balanced air pressure on the piston and allows the brakes to release.

In this way, the follow-up valve applies or releases the brakes exactly in response to the brake pedal, allowing the driver accurate control of the power braking system.

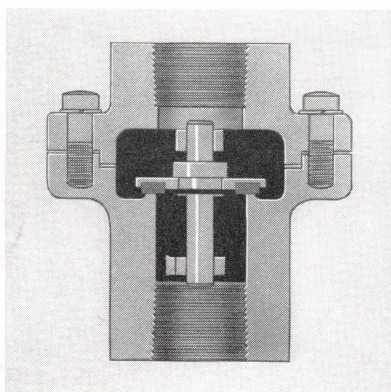
Check Valve

In practical installations, it is found desirable to install a check valve in the vacuum line near the intake manifold. This check valve allows air to be drawn out of the system into the manifold but automatically prevents the reverse action of air passing into the system from the manifold. Strictly speaking, a check valve is not essential for operation of the system; its use is highly recommended, however, first, to prevent combustible vapor from passing into the lines and second, to maintain vacuum in the system should the engine be stopped with the brakes applied.

Two types of check valves are used:

- 1—Plain check valves.
- 2—Power check valves.

Plain Check Valve



Outside and sectional views of a plain check valve for trucks and tractors (B-K type VC Valve).

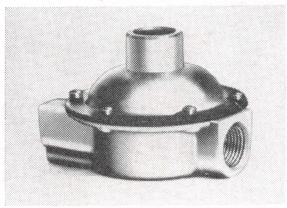
Above is illustrated the B-K unit known as the VC Check Valve for use on truck or tractor systems.

The valve proper is free to move vertically and rests by gravity on the valve seat, therefore the unit must always be mounted vertical, as shown. The valve is faced with a resilient material similar to rubber, but which is not affected by gasoline or oil. This resilient surface insures a better fit on the seat than metal-to-metal contact, and therefore aids in leak-proof operation.

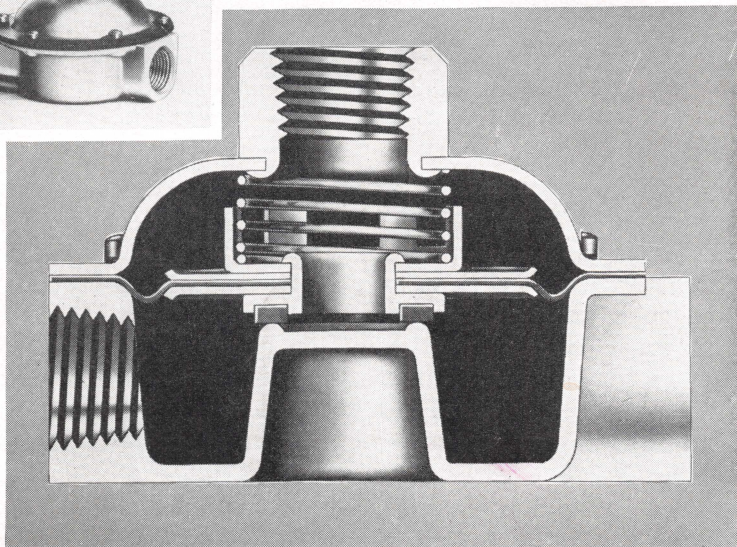
The upper port is connected to the intake manifold, and the lower port is connected to the vacuum power brake system. When the intake manifold vacuum is greater than that in the power brake system, the valve automatically lifts from its seat and allows air to be drawn out of the system. Air flow in the reverse direction is prevented by the valve returning to its seat when the manifold vacuum is equal to, or less than that in the brake system.

Power Check Valve

The following pictures show the B-K type PV Power Check Valve which includes features to insure more rapid and more

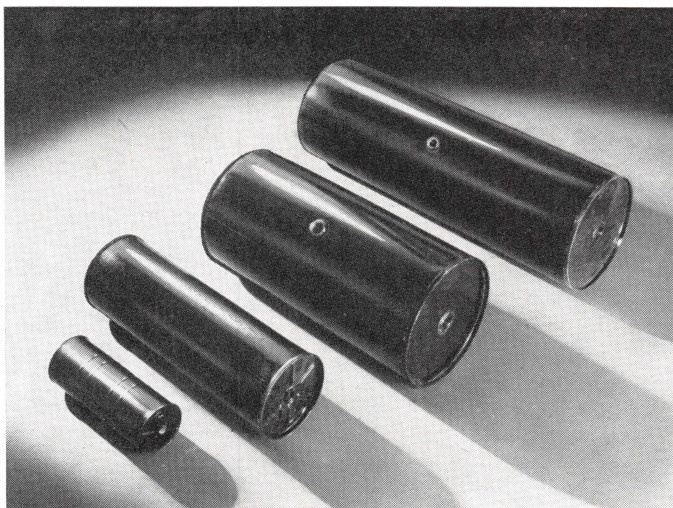


*Outside and sectional views of a power check valve for trucks and tractors.
(B-K type PV Valve.)*



positive seating of the valve. The large area of a flexible diaphragm provides more square inches of surface for manifold pressure to work against in returning the valve to its seat and for holding the valve in the closed position. The PV Valve is preferable to the VC Valve for heavy-duty installations or where a leak-proof seal, under all conditions, is important.

Vacuum Reservoir

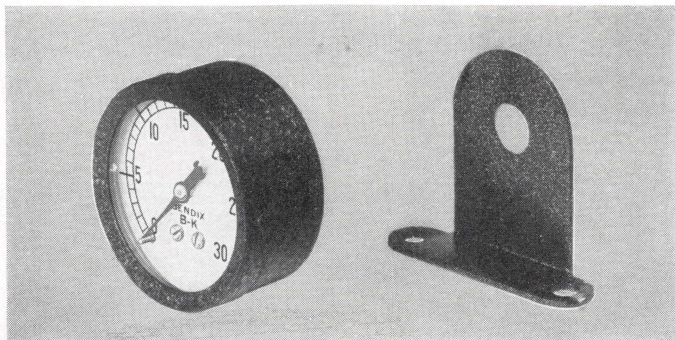


Various size reservoirs are available to suit the requirements of individual installations.

A vacuum reservoir is a highly justified addition to vacuum power brake installations. Such a reservoir, consisting of a steel tank with suitable connections, is installed in the vacuum line between the check valve and the control valve. As the engine operates, reserve vacuum is trapped and stored in the reservoir due to the action of the check valve. Because the vacuum in the reservoir is maintained at or near the maximum available, the power and speed of brake application are increased; moreover, reserve vacuum is provided so that if the engine is stopped, there is sufficient vacuum for several brake applications or for holding the brakes applied for a considerable period of time.

Vacuum Gauge

A vacuum gauge installed on the instrument panel serves to keep the driver informed of the vacuum available in the system for brake application just as an ammeter and oil pressure gauge allow him to observe the functioning of the electrical and lubricating systems.



Vacuum gauge for instrument panel or steering post mounting.

A vacuum gauge is an important safe-guard against emergencies arising from broken vacuum lines or other accidental damage to the power brake system.

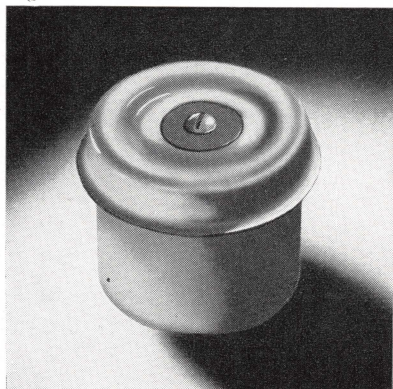
The safety valve of the vacuum gauge is recognized by New



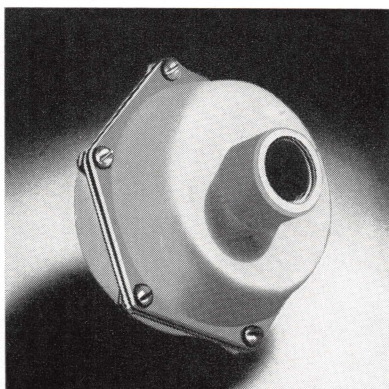
York state to the extent of making such equipment compulsory by law; other states are likely to follow with similar laws.

Air Cleaners

It is important to protect the inside working parts of the power brake system from dust and foreign matter. This is accomplished by the use of air cleaners where outside air is introduced into a system. As pointed out, many B-K units have built-in air cleaners which filter the incoming air through a thickness of curled hair.



Remote type air cleaner.



Cartridge type air cleaner.

Other B-K units call for the use of separate air cleaners which are either attached direct to the unit or connected to it by a length of hose. This remote location of the air cleaner is always advisable where the installation unavoidably exposes the unit to splash or dust. Remote air cleaners are sometimes installed inside the cab or, at any rate, in a position on the chassis affording greatest protection from road dust and splash.

The above illustrations show typical B-K air cleaners. The one on the left is suitable for remote location. If remote location is not warranted, however, the threaded fitting at the bottom may be screwed directly into the port on the cylinder or valve.

The cartridge type air cleaner (see illustration) is for use in vacuum lines on tractors and trailers. It is usually located close to the terminal from which the jumper hose connects the two vehicles. Such an air cleaner serves to filter the outside air which rushes into the system when the two vehicles are disconnected. Without this protection, dirt finding its way into the system will reach the working parts of valves and cylinders, causing rapid wear, sticking of moving parts and eventually leads to extra expense for repairs. For these reasons it is wise economy in the long run to provide complete air cleaner protection.

The Complete Atmospheric Suspended System For Trucks

In the installation diagram below, the complete atmospheric installation is shown for a truck with the vacuum reservoir and vacuum gauge indicated as optional recommended equipment;

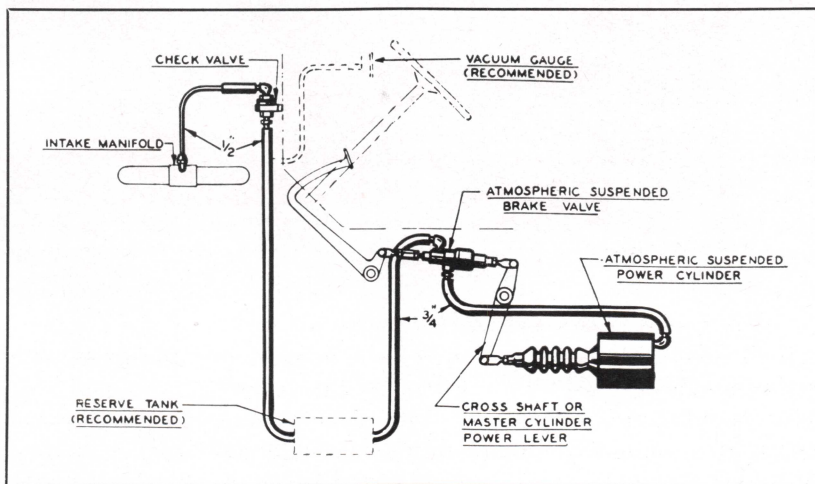


Diagram of complete atmospheric suspended truck installation showing the reservoir and vacuum gauge as optional equipment.

the check valve is considered a definite requirement. Diagrams for alternative installations are shown later under Typical B-K Installations.

TRUCK SYSTEM, VACUUM SUSPENDED

Larger trucks require power cylinders of larger bore and stroke to provide sufficient power for full brake application. As we have seen, if the cubic capacity of the power cylinder exceeds certain limits, the large volume of air suddenly introduced into

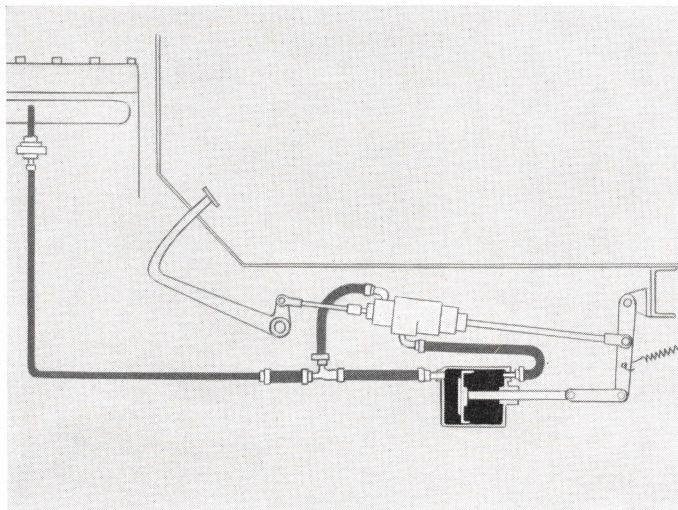


Diagram showing the relation of units and connections for a vacuum suspended system on a truck.

the intake manifold may interfere with engine operation. Moreover, evacuating the larger cylinder by moving a large volume of air through hoses and valves causes a time lag in brake operation which it is desirable to avoid.

In a vacuum suspended system, when the brakes are applied there is little movement of air out of the cylinder, (theoretically, none for perfect vacuum). When the brake pedal is released, pressures on both sides of the piston are instantly equalized through the control valve, thus releasing the brakes; after this the partial vacuum then existing in the system is brought back to the maximum available.

Because of these features, the vacuum suspended system has become generally accepted for larger vehicles.

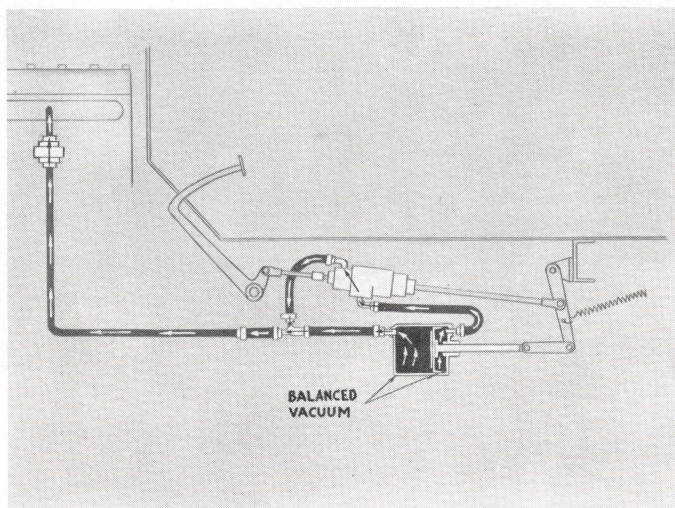
The basic units of the vacuum suspended system are similar to the atmospheric suspended system; they consist of a power

cylinder, an operating valve and hose connections. In the vacuum suspended system, however, a seal is provided around the piston rod of the power cylinder so that vacuum can be maintained on both sides of the piston. One end of the power cylinder is connected to the intake manifold through the control valve; the other end of the cylinder is directly connected to the intake manifold.

Released Position

When the brakes are released, the control valve connects one end of the power cylinder to vacuum; since the other end is directly connected to vacuum, the power cylinder piston is subject to equal vacuum on both sides and no pull is exerted.

Because the hose line which connects directly from the power cylinder to the intake manifold is subject to vacuum whenever the engine is operating, it is known as the "constant vacuum



Released position in a vacuum suspended system, showing the power cylinder piston balanced between equal vacuums.

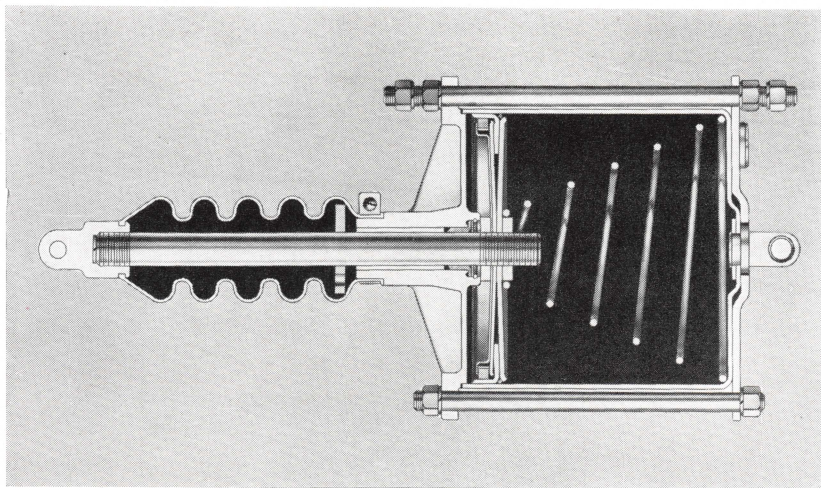
line" or simply the "vacuum line." The other line which runs from the power cylinder to the control valve is known as the "control line"; it is subject to vacuum when the brakes are off and to atmospheric pressure when the brakes are on.

The end of the power cylinder to which the control line leads is known as the control end; the other end of the cylinder is the constant vacuum end.

Brakes Applied

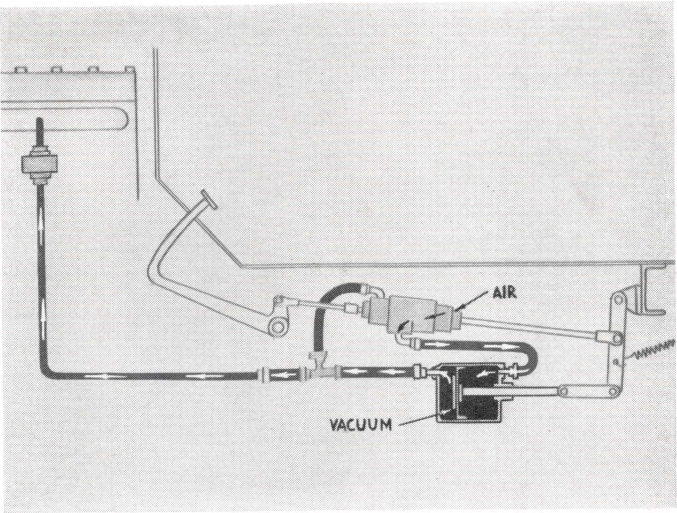
When the brake pedal is depressed, the control valve closes the vacuum passage and opens the control line to air; thus it connects the control end of the cylinder to outside air pressure. The result is the piston is forced into the cylinder by atmospheric pressure, applying the brakes. The vacuum suspended control valve works on the same follow-up principle as in the atmospheric suspended valve, having applied, hold and released positions. (See illustration opposite.)

Power Cylinder

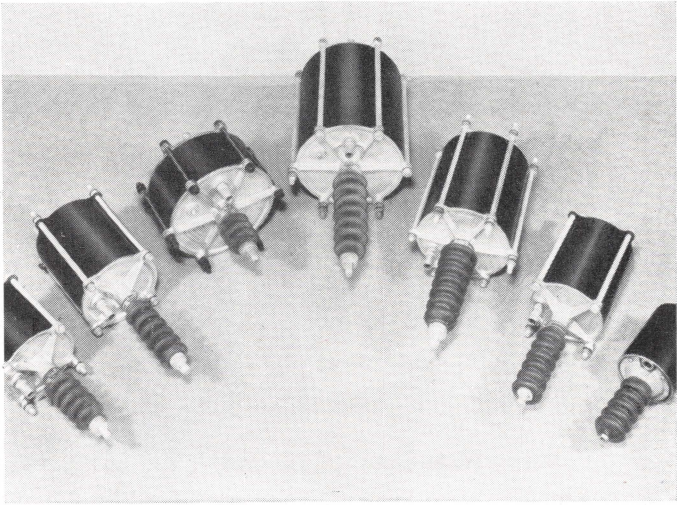


Vacuum suspended power cylinder.

The inside construction of a typical vacuum suspended power cylinder is shown in the illustration above. Note the seal around the piston rod to permit holding vacuum on the rear side of the piston. The rear end plate has a threaded port to permit attachment of the vacuum line similar to the front end. Piston construction is similar to that previously described for atmospheric suspended cylinders.



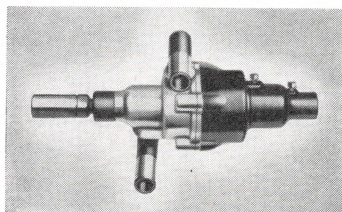
Applied position in a vacuum suspended system, showing one side of the piston under atmospheric pressure while the other side remains under vacuum.



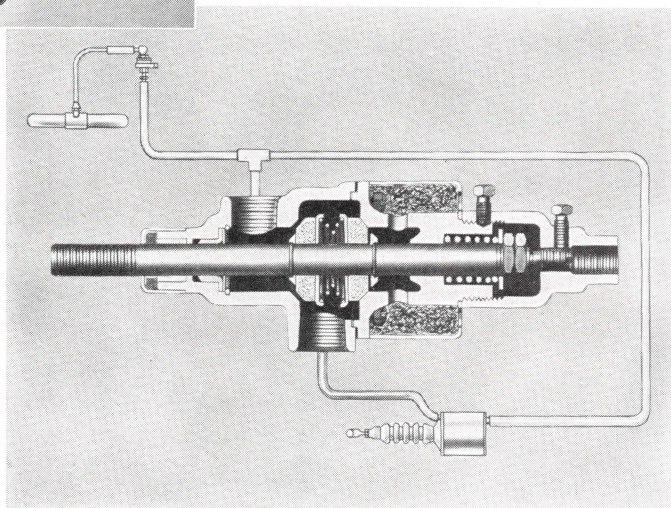
Representative group of vacuum suspended B-K power cylinders, showing range in sizes for various applications.

Control Valve

In the illustration below, a sectional view of a vacuum suspended control valve (B-K XT-1½ Valve) is shown in released



Outside and sectional view of vacuum suspended control valve with connections to the system indicated diagrammatically.



position with connections to the system indicated diagrammatically.

The valve discs within the valve housing are made of resilient material to insure a leak-proof fit on the seats. Both discs are free to slide a short distance on the valve rod, but are limited in travel by retainer washers and springs. The valve discs are pressed outward against these stops by a coiled spring located between the discs.

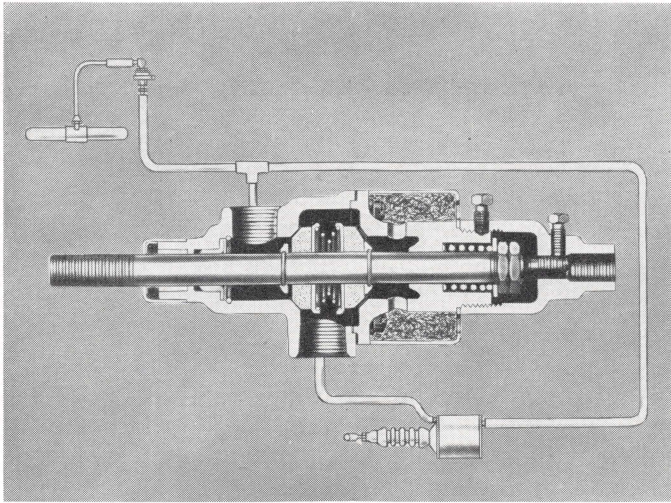
The larger spring at the end of the valve rod is to bring the valve into released position when there is no tension on the brake rod. Connection to the brake rod is through the valve rod on one end and through the valve housing on the other.

Note that this valve is provided with a built-in air cleaner packed with curled hair, to catch dust and foreign matter.

Released. The released position, illustrated on the opposite page, is automatically assumed when there is no pull on the brake rod, which corresponds to a fully released brake pedal. In this position, the vacuum port is open, connecting the control end of the power cylinder to vacuum. The power cylinder piston is therefore suspended between equal vacuums.

Applied. The first action as the driver steps on the brake pedal is to put tension on the brake rod. This tends to "stretch" the valve assembly, that is to pull the valve rod away from the valve housing.

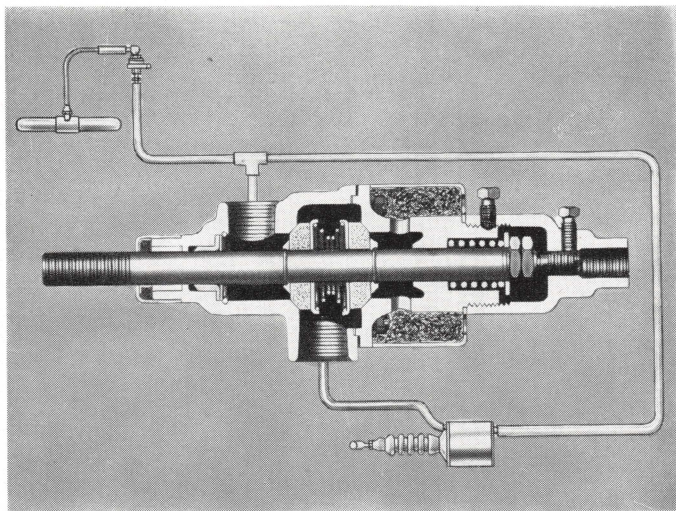
Tension on the valve moves the valve discs, first closing the vacuum port and then opening the air port. With air in the control line, one side of the power cylinder piston is subject to



Control valve in applied position; the control line and control side of the power cylinder piston are open to atmospheric pressure.

atmospheric air pressure while the other side remains under vacuum; consequently, the brakes are applied.

Holding. It will be noted from the foregoing description of brake application that the vacuum port is closed before the atmosphere port is opened. There is a short interval,



Control Valve in holding position; both valves closed.

therefore, in which the valve action overlaps, that is in which both valves are seated. This provides the “lapped” or “hold” position as follows:

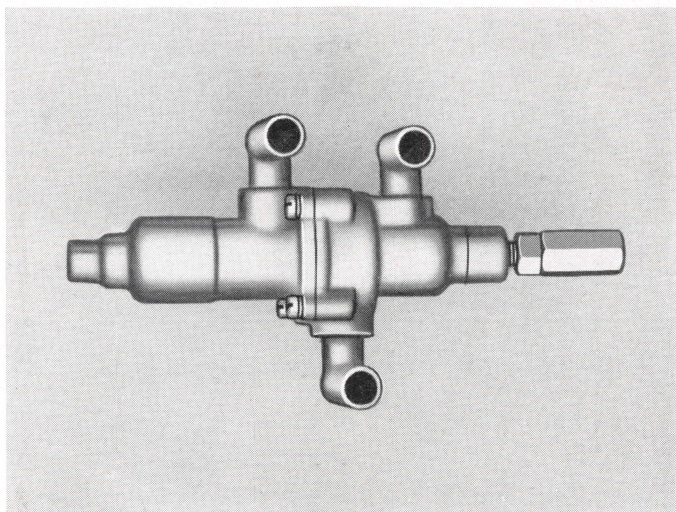
Assume the driver applies the brakes to the half-way position and then holds the pedal as in a partial brake application. The power cylinder momentarily continues to pull and thus to move the brake rod in the applied direction. This action continues until the atmosphere valve disc also rests on its seat. This stops further cylinder action before it has gone to the point of opening the vacuum valve. Because both valves are closed, the degree of vacuum then on the control side of the piston is held and thus the brakes remain partially applied in obedience to the position of the brake pedal.

It is apparent that the holding position is an intermediate position between applied and released, in which both valve discs are on their seats.

With the valve in holding position, further tension on the brake rod (corresponding to more pressure on the pedal) would again bring the valve into applied position; less tension on the brake rod (corresponding to less pedal pressure) would bring the valve into released position.

Remote Air Cleaner Type Control Valve

The XT- $\frac{1}{2}$ Valve is also available with a fitting for connection to a remote air cleaner as shown below, instead of with an integral air cleaner. The remote air cleaner type valve is recommended for use in dusty areas or when the installation is such that the operating valve is unavoidably exposed to road dirt.



XT- $\frac{1}{2}$ Valve with fitting for remote air cleaner.

Large-Capacity Control Valve

The Super-X is a large capacity vacuum suspended control valve identical in principle to the XT- $\frac{1}{2}$. Larger passages and larger valve discs provide the greater capacity necessary for use with large power units or to operate multiple power unit installations.

Check Valve

The check valve in the vacuum suspended system, similarly to the atmospheric suspended system, is considered an essential unit. It traps vacuum at the high point as the engine operates and holds this maximum vacuum in readiness for brake application. It is, of course, an indispensable unit if a vacuum reservoir is to be used.

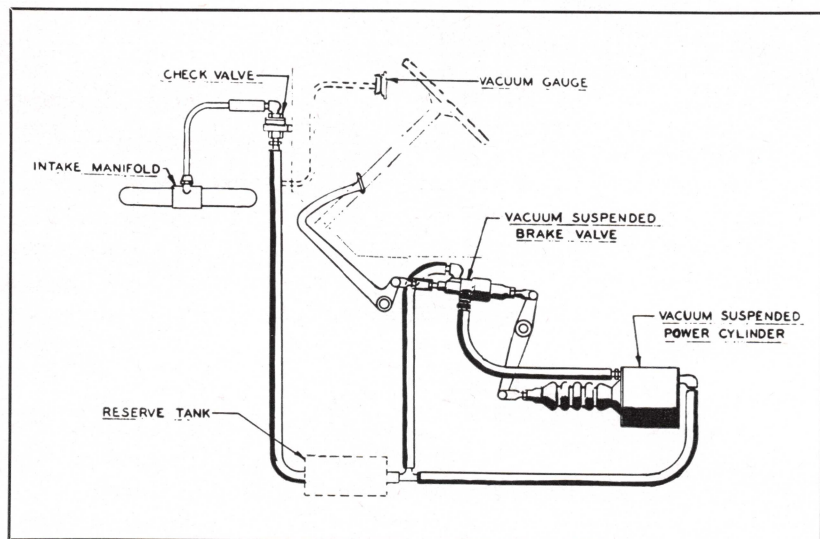
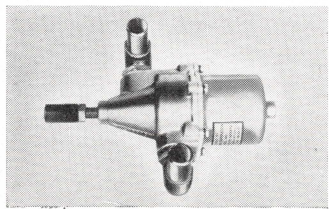
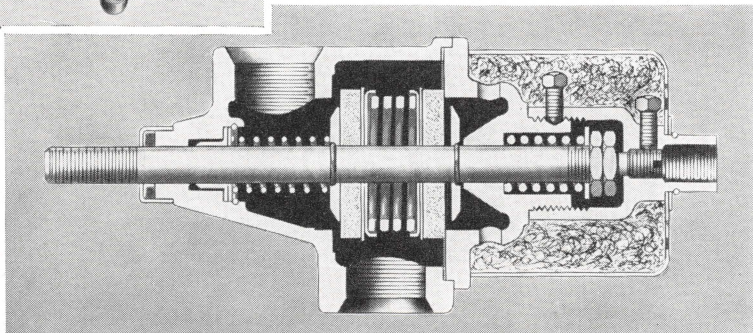


Diagram of complete vacuum suspended truck installation.



B-K Super-X Control Valve for large installations requiring extra valve capacity.



Reservoir and Gauge

The uses of the vacuum reservoir and the vacuum gauge on the vacuum suspended system are the same as on the atmospheric suspended system. They are both highly desirable units in the interest of safety and the most efficient brake operation.

The Complete Vacuum Suspended System for Trucks

In the diagram opposite, the complete vacuum suspended installation is shown for a truck, with the vacuum gauge and reservoir indicated as optional recommended equipment. Diagrams for alternative installations are shown later under Typical B-K Installations.

"Double-Line" and "Single-Line"

The term "double-line" is sometimes used to indicate the vacuum suspended system, and "single-line" for the atmospheric suspended system. These terms, although conveniently short, are misleading since as will be shown later some "two-line" systems are atmospheric suspended, and on the other hand, certain vacuum suspended systems have only one line to the cylinder. It is better to use the longer but more accurate terms of "vacuum suspended" system and "atmospheric suspended" or "air suspended" system to avoid confusion.

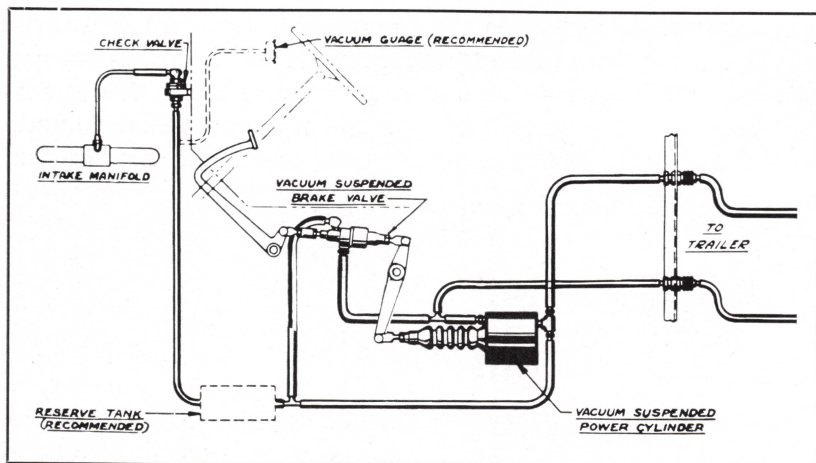
TRACTOR SYSTEM

Basically, the tractor installation is identical with the truck installation except that provisions must be made to connect the tractor system to the trailer system so that the trailer brakes are applied at the same time and to the same degree as the tractor brakes.

In its simplest form this would involve only extending the lines from the tractor control valve so that they serve the trailer cylinder as well as the tractor cylinder. The practical requirements of trailer operation, however, introduce other units which will be discussed under trailer systems.

Connections Between the Vehicles

Jumpers. Connections between tractors and trailers are through two loops of vacuum hose called jumpers; these are long enough to allow the necessary movement between the two vehicles and for convenience in making up the connections.

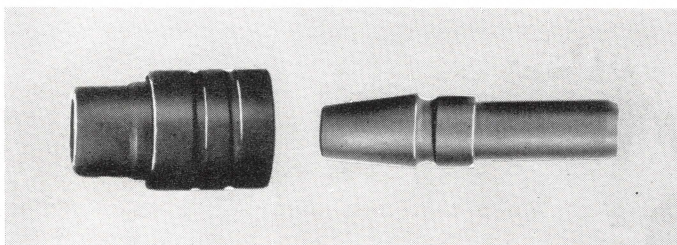


Typical tractor installation of the vacuum suspended type.

Suspension springs are usually provided which serve to support the jumpers and prevent them from rubbing against the vehicle when traveling on the road.

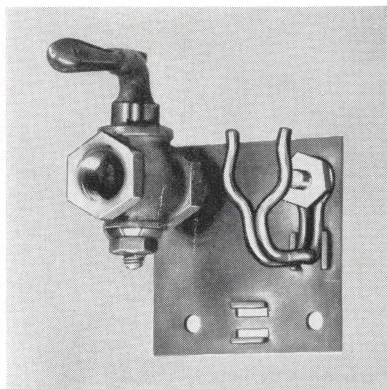
It is customary to make the installation so that the control line is at the left of the vehicle and the vacuum line at the right; uniformity in this regard obviously avoids confusion.

Hose Couplings. A special type coupling is available for jumper hoses which provides a positive air-tight connection and which can be quickly attached or disconnected. This coupling consists of two units: a tapered hollow plug which is attached to the end of the jumper hose running from the tractor, and a corresponding receptacle which is attached to the trailer. The two units slip together to form an air-tight joint and are held in place by an annular snap spring within the female unit.



Coupling for jumper hose between the tractor and trailer.

Shut-off Valves. The tractor connections are ordinarily provided with shut-off valves for use when the trailer is disconnected. The shut-off valve is mounted directly

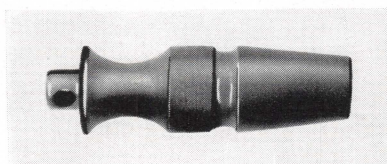


B-K shut-off valve and mounting bracket. Notice clip to hold the jumper hose when it is disconnected.

on the tractor and the jumper hose is attached to the shut-off valve by means of a threaded nipple. Shut-off valves allow operating the tractor power brake system when the trailer is not being pulled; also, if these valves are closed before the trailer is disconnected, a sudden rush of air and outside dust into the tractor system is prevented at the time the hose couplings are pulled apart.

A convenient form of shut-off valve and bracket assembly is illustrated at the left.

Stopper Plugs. Frequently trailers must stand for considerable periods of time without the tractor lines attached. To prevent moisture and dirt from finding its way

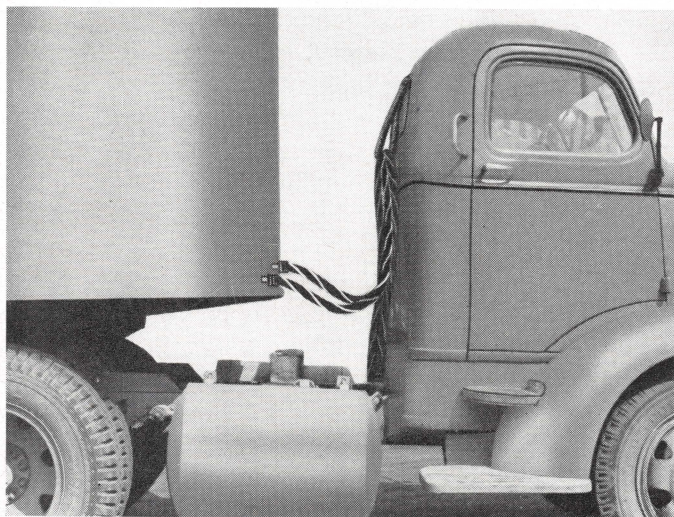


Stopper plug for use in trailer hose coupling when the tractor is disconnected.

into the trailer lines through open hose couplings under these conditions, stopper plugs are provided. These plugs are tapered, and fit into the female hose coupling on the trailer in place of the coupling plug. An air-tight seal for the trailer system is thus provided.

Hand Control of Trailer Brakes

When trailers must be operated under severe road conditions, such as hills and slippery pavements, hand control of the trailer brakes is a definite safety feature. It gives the driver full control of the trailer brakes independent of the tractor braking system, and, because the train can be retarded from the trailer, it helps avoid dangerous skids and loss of control.



Jumper connections between tractor and trailer.

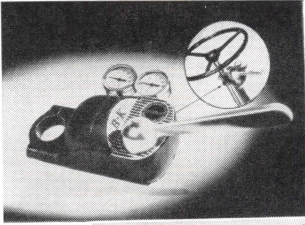
Also any tendency for the trailer to weave can be overcome by partial application ("snubbing") of the trailer brakes without applying the tractor brakes.

Independent control of the trailer brakes is provided by a hand control valve mounted on the steering column or on the instrument panel, whichever is the more convenient in the individual installation. The arrangement usually is such that the foot pedal applies brakes on both vehicles; the hand valve, however, operates only the trailer brakes.

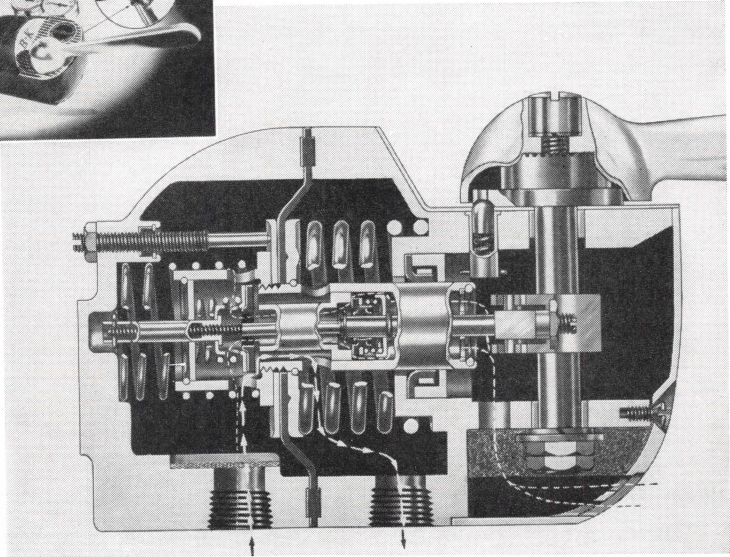
The B-K RH Hand Control Valve shown in the illustration opposite is available for either vacuum or atmospheric suspended systems and incorporates features to insure accurately graduated control.

The hand valve may be obtained with two vacuum gauges as illustrated. One of these gauges shows the available vacuum for brake application and the other shows the vacuum on the control side of the system.

The sectional view shows a vacuum suspended RH Valve in released position with air passages indicated by arrows and



Left: RH Hand Control Valve and typical installation. Below: Sectional view through RH Hand Control Valve.



dotted lines. Poppet valves are controlled by the position of the handle, but the valve seats are positioned by movement of the diaphragm. The passage of air through the valve may be traced by following the dotted line. The arrows indicate the vacuum passages.

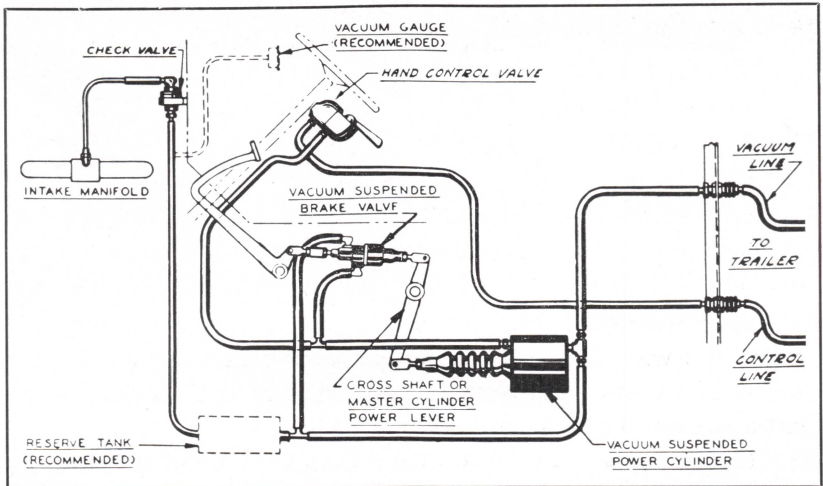


Diagram of trailer installation with hand control for trailer brakes.

TRAILER SYSTEM, VACUUM SUSPENDED

Assuming that the tractor or towing vehicle is equipped with a vacuum suspended system, a corresponding vacuum suspended system for the trailer would, in its simplest form, consist only of a power cylinder (or diaphragm) and two connecting lines to the tractor. On such a system, one line (right side of the vehicle) would connect the constant vacuum side of the trailer cylinder to the tractor system vacuum line. The other line (left) connects the control side of the trailer cylinder to the tractor system control line.

In this simple type hook-up, the tractor valve would directly control both the trailer cylinder and the tractor cylinder with equal effect for all degrees of brake application and release.

Trailer Valves (Relays)

While a trailer system consisting only of a power cylinder and connecting lines would work on small units, there is the disadvantage of moving a large volume of air through a long control line, which tends to slow down brake action. Moreover, operating both the tractor and the trailer power cylinder from one control valve crowds the port capacity of the valve and further tends to slow up brake action.

To meet this situation, the trailer usually is provided with a separate operating valve and a vacuum reservoir, both of which are located on the trailer comparatively close to the trailer power cylinder.

The vacuum reservoir serves, in a sense, as an independent source of vacuum on the trailer, although vacuum is maintained in the reservoir by connection to the tractor vacuum line and thence to the intake manifold.

In this way, the trailer power cylinder is provided with a source of vacuum and a control valve both located close by so that all units can be interconnected by short vacuum lines. This does away with the need of moving large volumes of air through long lines to the tractor, and therefore, speeds up brake action.

The trailer operating valve itself is controlled by a line connecting to the tractor control line and thence to the tractor operating valve.

The volume of air needed, however, to operate the trailer valve is very small compared to the volume that would be needed to operate the power cylinder. Movement of this small volume of air does not entail lag in brake operation as would be the case in direct operation of the trailer cylinder from the tractor valve.

The action might be compared to an electric relay system in which a comparatively weak current controlled by a remotely located push button operates a relay coil which in turn closes a much larger switch and starts a powerful electric motor. In this case, a small current controls a larger current through the mechanism of the relay. In the vacuum braking system a small volume of air controls the trailer valve and this valve in turn provides large, direct air passages to the power cylinder.

Because of this relay action, trailer valves are ordinarily called relay valves. Details of construction and operation of various types of B-K relay valves will be covered later.

Automatic Brake Application

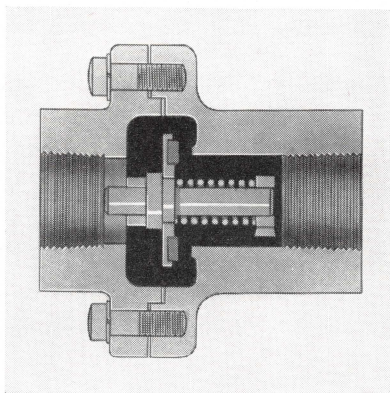
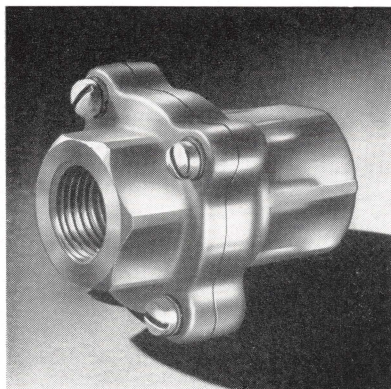
A hazard to be guarded against in the operation of tractor-trailer units is accidental disconnection of the trailer. Such an occurrence can lead to extremely serious consequences, particularly if it should happen on an up-grade. Of course, all mechanical precautions are taken in the coupling mechanism to prevent break-aways but nevertheless records show that break-aways do occur. The possibility of break-away is recognized by Interstate Commerce Regulations and other laws to the extent of requiring the trailer to be provided with means of automatic brake application in the event of break-away, and for keeping the trailer brakes applied for a minimum of fifteen minutes.

When a trailer breaks away, both the vacuum line jumper and the control line jumper between the vehicles are, of course,

broken. Breaking the control line allows air to rush into the control ports of the relay. Introduction of air into the control line is exactly what takes place in normal operation when the brakes are applied on a vacuum suspended system. On the other hand, without provision against it, breakage of the constant vacuum line would lose the vacuum from the trailer system which ordinarily would be available for brake application.

Trailer Emergency Check Valve

A simple check valve arrangement eliminates this loss of vacuum by automatically sealing the constant vacuum line ahead of the reservoir. A special check valve is installed in the constant vacuum line between the reservoir and the coupling. This check valve is held open by light spring pressure and remains open under all normal operating conditions. This is necessary to insure equal vacuums in the vacuum line and control line; if the check valve closed, it might hold momentarily, a higher vacuum in the vacuum line than exists in the control line which would cause partial brake application.

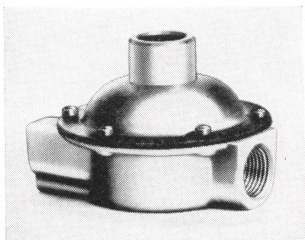


Plain type trailer emergency check valve (B-K type TC Valve) for automatically sealing vacuum in the reservoir in the event of break-away. In the sectional view, note the spring which normally holds the valve open; this is the only structural difference between this type valve and the VC Valve for trucks and tractors.

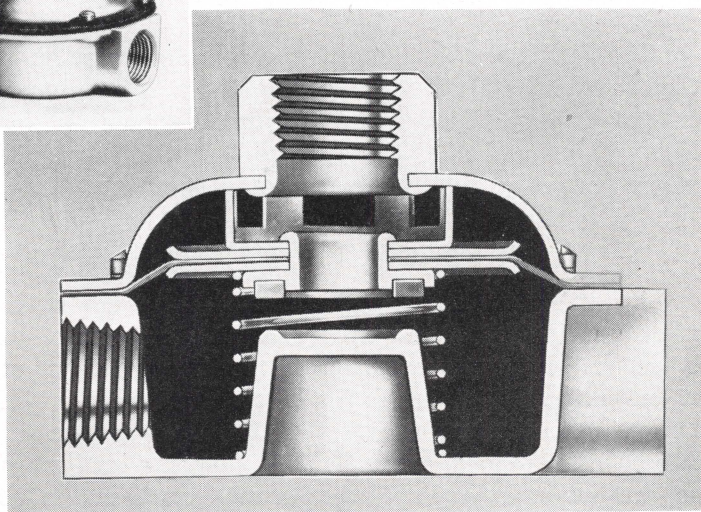
When break-away occurs, the force of outside air against the valve disc overcomes the light spring pressure and closes the valve; this seals the vacuum in the reservoir. Thus, when both lines part, the constant vacuum line is automatically sealed against loss of vacuum; while at the same time the control line is opened to atmospheric pressure which applies the brakes.

The capacity of the reservoir is sufficient to hold the trailer brakes applied for a considerable length of time (fifteen minutes minimum required by law).

Power Type Trailer Emergency Check Valve

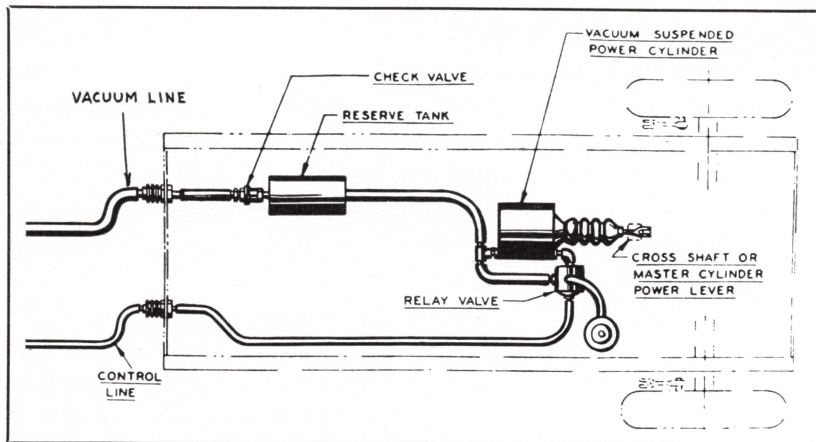


B-K type PT Power Emergency Check Valve. Note the spring which holds the valve open during normal operation.



The power type PT Emergency Check Valve is a heavy-duty check valve for use on trailers. It is structurally similar to the PV Valve for trucks and tractors, except the spring is placed so as to hold the valve open during normal operation. Due to the diaphragm construction, there is a larger area for outside air pressure to act upon and as a result the valve closes faster and maintains a more positive seal.

The Complete Vacuum Suspended Trailer System



Vacuum suspended trailer system with relay and reservoir.

The diagram above shows the complete vacuum suspended trailer brake system for operation with a vacuum suspended tractor system. This trailer system is shown with a B-K PR Relay Valve, and a TC Emergency Check Valve providing automatic "break-away" application of brakes.

TRAILER SYSTEM, ATMOSPHERIC SUSPENDED

Assuming an atmospheric suspended tractor system, the atmospheric suspended trailer system again builds up from the basic units of a power cylinder (or diaphragm) and a single vacuum line connecting to the tractor system. The same need, however, exists for a relay valve and vacuum reservoir to insure fast operation of trailer brakes. This addition requires a separate vacuum line to maintain reservoir vacuum, so that the connections between the vehicles consist of a constant vacuum line to the reservoir and a control line to the relay. (Note that this is a "double-line" system even though both the tractor and the trailer systems are atmospheric suspended.)

Automatic Brake Application

At this point, observe again these fundamental differences between vacuum suspended and atmospheric suspended systems :

Atmospheric Suspended System

Vacuum in the control line applies brakes.

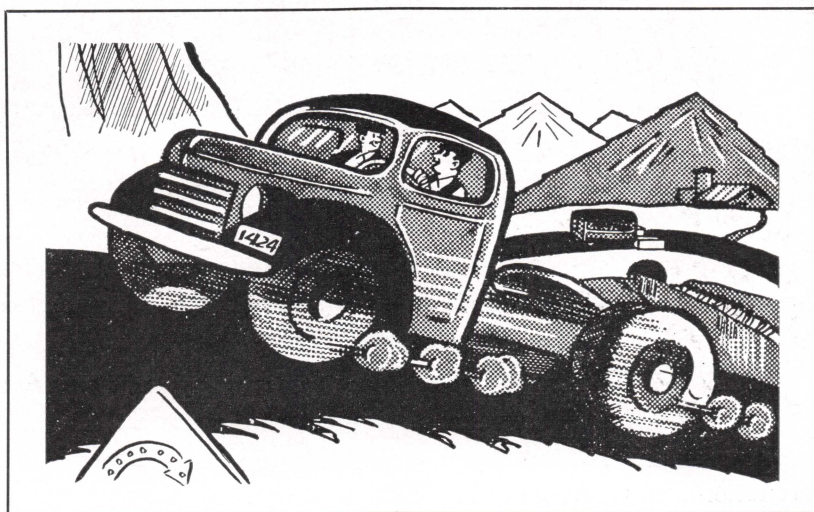
Vacuum Suspended System

Air in the control line applies brakes.

Accidental break-away opens both the lines to atmosphere, but air in the control line of an atmospheric suspended system is the condition which normally *releases* the brakes.

The relay valve for atmospheric suspended systems incorporates a feature which offsets this condition and provides automatic break-away application of brakes.

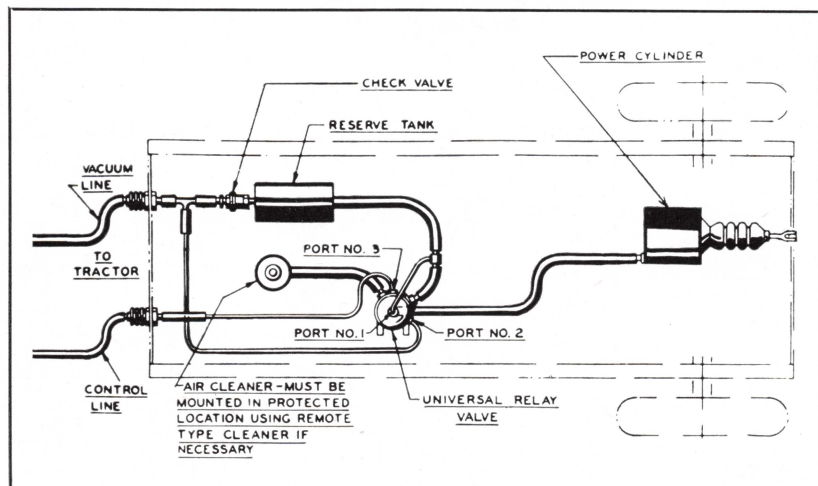
Details of trailer valves will be discussed later, but at this time it may be said that a separate emergency control line runs from the relay valve to the constant vacuum line at a point between the check valve and the hose coupling. This section of the vacuum line is of course normally under vacuum; therefore, the emergency line to the relay normally carries vacuum. When break-away occurs, air rushes into the constant vacuum line up to the point where the check valve is located. When this happens, the emergency line to the relay is subject to air pressure, although vacuum is maintained in the reservoir. This air pressure is utilized through the relay valve to apply the brakes.



"The way this baby climbs you'd never think we were pulling a trailer."

—Courtesy of GO MAGAZINE.

The Complete Atmospheric Suspended Trailer System



Atmospheric suspended trailer system including break-away feature.

The diagram above shows the complete atmospheric suspended trailer system for operation with an atmospheric suspended tractor, using a B-K Universal Relay.

CONNECTING DISSIMILAR TRACTOR AND TRAILER SYSTEMS

So far, it has been assumed that the tractor system and the trailer system are of the same type; that is, that both vehicles are equipped with either atmospheric suspended or vacuum suspended systems. In practice, however, it often becomes necessary to operate either a vacuum suspended tractor with an atmospheric suspended trailer or an atmospheric suspended tractor with a vacuum suspended trailer.

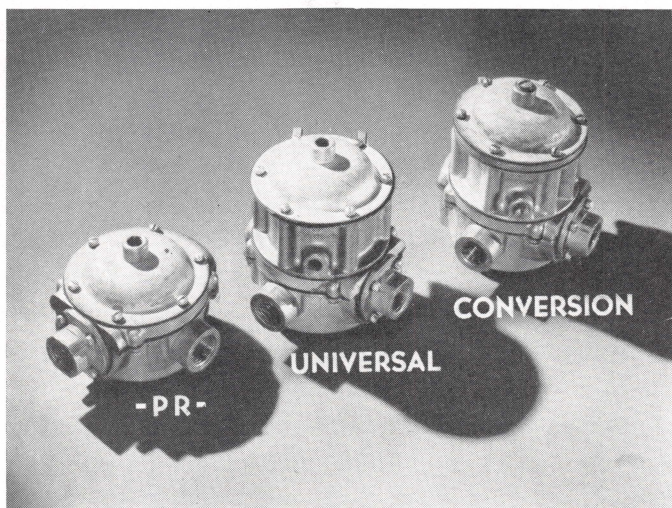
Such combinations are made possible by relay valves which provide for control between dissimilar type systems. Details of how this is accomplished are explained later under "Construction and Operation of B-K Relays." The following chart, however, is a quick guide to the B-K relays required for the various possible combinations of tractors and trailers.

Trailers

Tractors	Vacuum Suspended	Atmospheric Suspended
Vacuum Suspended	PR Relay	Conversion Relay
Atmospheric Suspended	Universal Relay	Universal Relay

Relays for various combinations of systems.

From this chart, it will be noticed that the Universal Relay permits an atmospheric suspended tractor to operate with either a vacuum or an atmospheric suspended trailer. Use of a vacuum suspended tractor requires the PR Relay on a vacuum suspended trailer and a Conversion Valve on an atmospheric suspended trailer.



Three commonly used B-K trailer operating valves or relays.

MORE ABOUT POWER UNITS

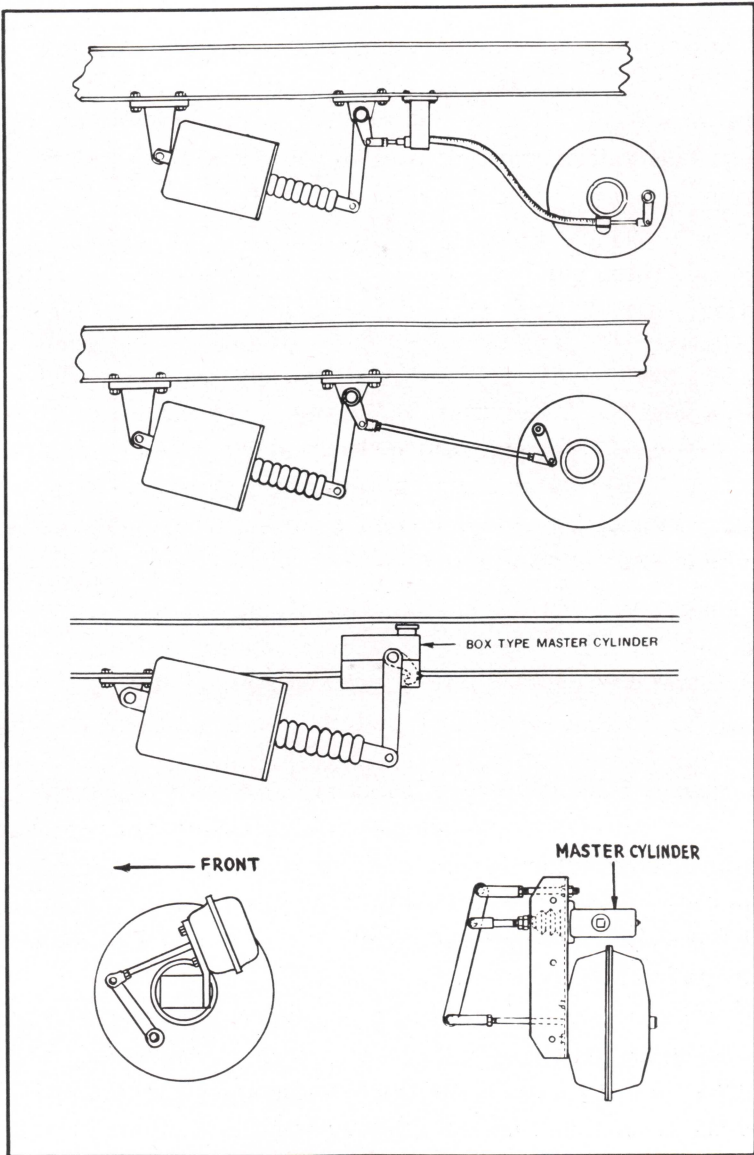
Direct-Pull Rating. For the purpose of rating the pulling power of cylinders (or diaphragm power units) on a uniform basis, a vacuum of 20" of mercury is assumed. This is equivalent to a working pressure differential of ten pounds per square inch. Therefore, the area of the piston in square inches, multiplied by ten, gives the rated pull in pounds. Actually, this rated pull is subject to some reduction due to mechanical friction of working parts, but it serves as a practical standard for installation work.

Piston Stroke In addition to the pull in pounds, the distance and "Power". through which that pull is exerted is important in gauging the ability of a power unit to do work. This distance is determined by the maximum travel or stroke of the piston.

Mechanical work is the product of the force (piston pull) and the distance (stroke), usually expressed in inch-pounds. A cylinder having a 150-pound direct pull and five-inch stroke would be capable of 750 inch-pounds of work ($150 \times 5 = 750$).

Leverage. Vacuum power brake systems are frequently connected to the vehicle braking system through intermediate levers which serve to increase the pounds pull on the brake mechanism. In this way, the cylinder in the above example (capable of 750 inch-pounds of work) could be combined with levers to produce either a brake rod pull of 750 pounds over a distance of one inch, or a 75-pound pull over a distance of ten inches ($75 \times 10 = 750$). Similarly, by leverage, an unlimited number of combinations of pulls and distances could be derived from the same cylinder within the limit of 750 inch-pounds.

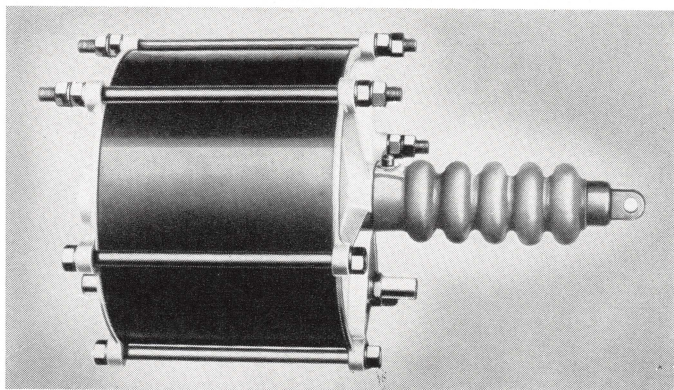
Use of leverage to increase pull at the expense of stroke or distance traveled, is called "compounding".



Typical power unit installations.

The B-K cylinder illustrated below is an example of a large power unit. The piston is $9\frac{1}{2}$ inches in diameter, with an area of 68 square inches. It is capable of a direct pull of 680 pounds with a vacuum of 20" of mercury. The stroke is $9\frac{5}{8}$ inches, giving it a work rating of 6,545 inch pounds.

Pushers, Pullers. The cylinders illustrated so far are of the "puller" type; that is, the working stroke is toward the cylinder. Cylinders are available, however, which work as "pushers;" that is, the work stroke is outward away from the cylinder. The nature of the individual installation



A large power cylinder (B-K type J cylinder, vacuum suspended).

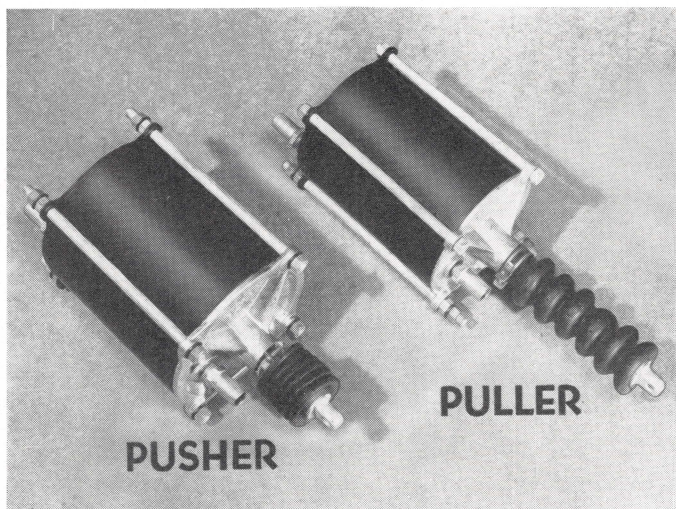
and available room determine whether the cylinder is to be of the pusher or puller type.

Pusher cylinders work on similar mechanical principles to the pullers, except the lip of the piston leather is reversed. A leather seal is provided around the piston rod to avoid air leaks where the rod works through the end plate.

Internal Valve Cylinders

The internal valve cylinder incorporates the control valve into the mechanism of the cylinder itself with the advantages of compactness and protection of working parts from dirt.

Details of internal valve cylinders will be discussed in connection with reactionary control since these cylinders are used entirely in combination with reactionary linkages.

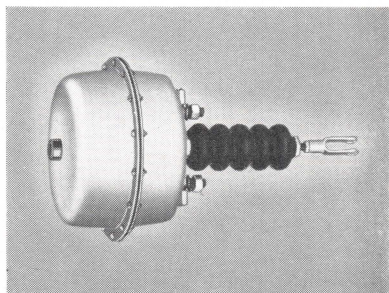
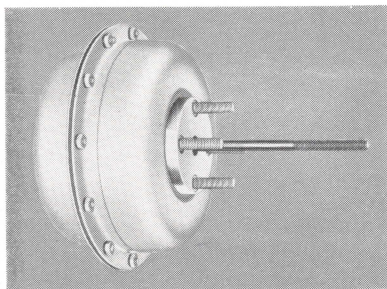


Two types of power cylinders.

Diaphragm Type Power Units

Diaphragm type power units are constructed on entirely different mechanical principles from power cylinders, although the operating result is the same; namely, to transform an air pressure difference into mechanical pull.

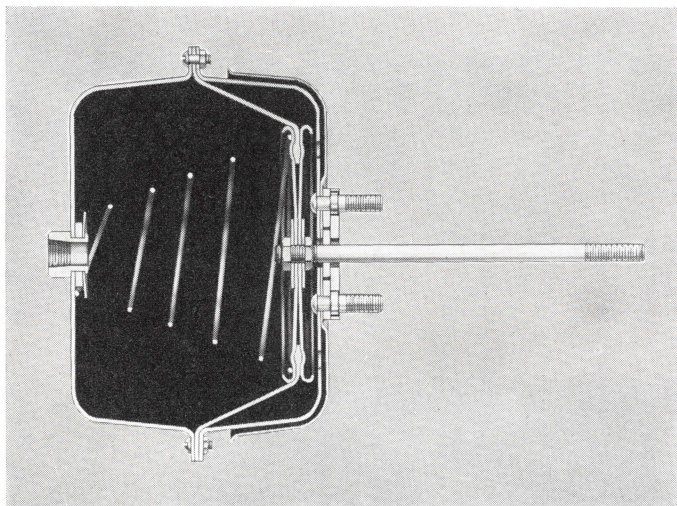
The illustration on the next page shows the internal parts of an atmospheric suspended diaphragm power unit. The diaphragm power unit consists of a metal shell which is divided



Diaphragm type power units: left, atmospheric suspended unit; right, vacuum suspended unit.

into two compartments by a flexible diaphragm. This flexible diaphragm is air-tight and the composition of which it is made has the property of resisting the action of gasoline and oil vapors. At the center, the flexible diaphragm is clamped between two steel plates which serve for attachment of the diaphragm rod and as a rigid surface for air pressure to act against.

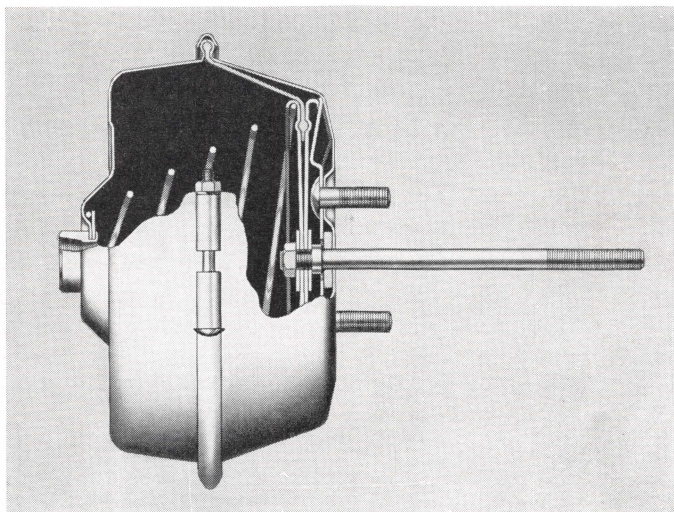
Diaphragm type power units have the advantage of mechanical simplicity and low initial cost; at the same time they require no maintenance attention such as lubrication or adjustment. They are, however, somewhat more bulky in size for equivalent power compared to cylinders and can only be made for comparatively short strokes; for these reasons, they are limited to applications where there is ample room and where only a short, direct pull is required.



*Section through diaphragm type power unit
(atmospheric suspended).*

Diaphragm power units are made for both atmospheric and vacuum suspended systems, but only as pullers, since the construction is not adapted to the pusher type.

D-84 and D-96 Diaphragm Type Power Units



The D-84 diaphragm power unit showing internal construction.

The D-96 is similar to the D-84 except it is larger in size and has a greater effective pull. Strokes of both units are the same.

The D-84 and D-96 diaphragm power units are late type atmospheric suspended B-K units having certain important new features of particular value on certain installations where space is limited.

The two halves of the shell are held together by a clamping ring which greatly simplifies disassembly as compared to the bolt ring construction. Since these units can be taken apart and reassembled faster, time and money are saved in service when, after periods of long use, the flexible diaphragm is to be replaced.

The shell design gives a practically constant pull throughout the length of the stroke, which means that maximum braking force can be applied to the brake operating lever throughout a greater arc of travel.

Likewise, this design is faster operating and somewhat more compact for a given power rating.

REACTIONARY CONTROL

In a physical braking system the required pedal pressure increases in proportion to the braking force; the harder the driver pushes, the more he applies the brakes. This gives a pedal "feel" that is an accurate gauge of braking force so that the braking effort can be suited to varying road and load conditions without over-braking or lock-wheel stops. Obviously in such systems, however, only a small part of the brake rod pull is felt against the driver's foot. The mechanical advantage of the brake pedal as a lever allows the driver to exert a brake rod pull of, say, 400 pounds, with a pedal pressure of perhaps only 100 pounds, and, as pointed out, power brakes would never have become necessary if there were room for a long enough brake pedal lever and if the driver's foot could feasibly traverse the long arc of such a lever.

Reactionary control was developed to provide vacuum power brakes with a graduated pedal "feel" even though the maximum pedal pressure may be quite small compared to foot-power braking.

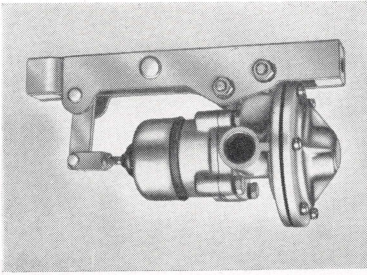
This type control is accomplished in one of two ways: (1) by incorporating a reactionary diaphragm in the control valve; (2) by external linkage.

Reactionary Control Valve (RXL)

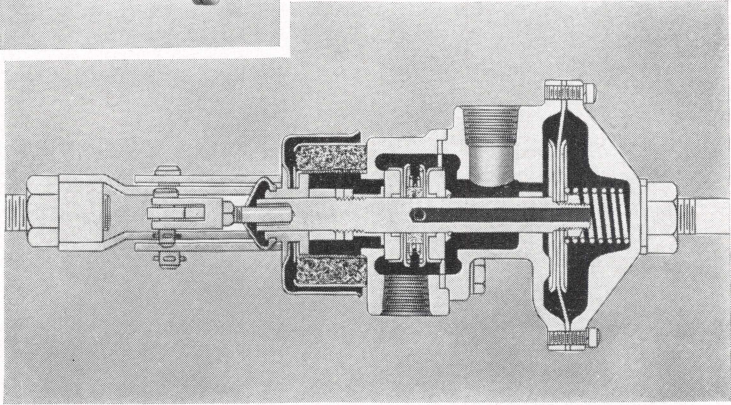
The B-K RXL Valve is a vacuum suspended valve which provided reactionary control. From the sectional view, on the opposite page, it will be noted that this valve is similar in construction to the valves previously described except the RXL has a flexible diaphragm and diaphragm chamber.

For the sake of understanding the operating principle, this diaphragm can be considered a miniature power unit; vacuum passages are so arranged that vacuum conditions on either side of the diaphragm are identical with vacuum conditions as they exist in the main power unit (cylinder or diaphragm).

The pull from this diaphragm increases or decreases the foot-power pull required to open the valve and to hold it open. The operation of the valve itself is otherwise identical with the XT-1½ Valve.



*Outside and sectional views of the B-K
RXL Valve which incorporates
reactionary control.*



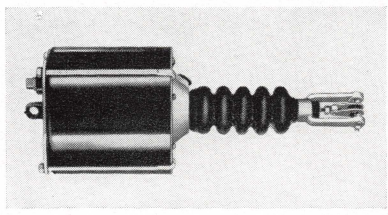
Because the diaphragm in the valve is subject to the same vacuum conditions as the main power unit of the system, the power output of the small diaphragm is exactly proportional to the power output of the large power unit, but of course much smaller in amount. Therefore, the resistance which the driver's foot must overcome to open the valve and hold it open, increases and decreases exactly in proportion to the power output of the brake system power unit. That is to say the reaction against the driver's foot is exactly proportional to the degree of brake application.

The external linkage shown with the RXL Valve provides connections to the brake rod so that the valve itself is offset from the direct line of the brake rod. This arrangement simplifies installation problems since the valve can be mounted in a brake rod which comes close to the floor board or other chassis parts; likewise the leverage of the offset linkage insures ample reactionary force from a comparatively small diaphragm, thus making the valve more compact.

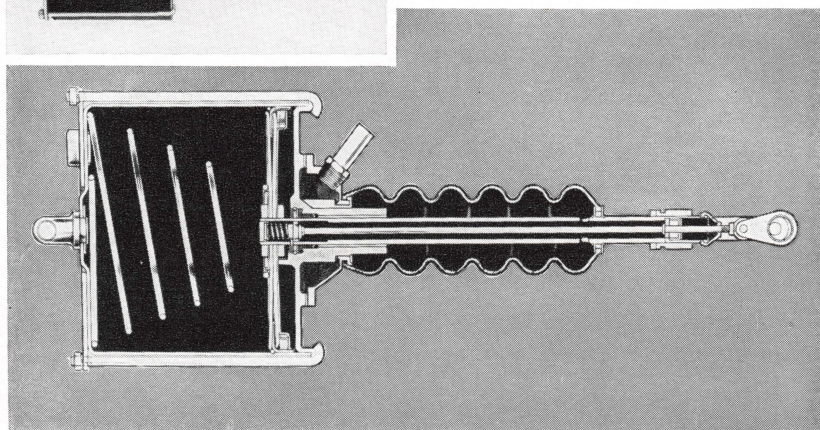
Internal Valve Cylinders

Study of the sectional view below will show that the internal valve cylinder combines the familiar elements of a vacuum suspended cylinder with a sliding control valve which works inside the hollow piston rod. The valve rod which operates the valve extends outward through the hollow piston rod. This valve rod is so placed that the pressure from the driver's foot, tending to push the piston rod in the direction of brake application, has the effect of first opening the valve and thus causing the power cylinder to operate.

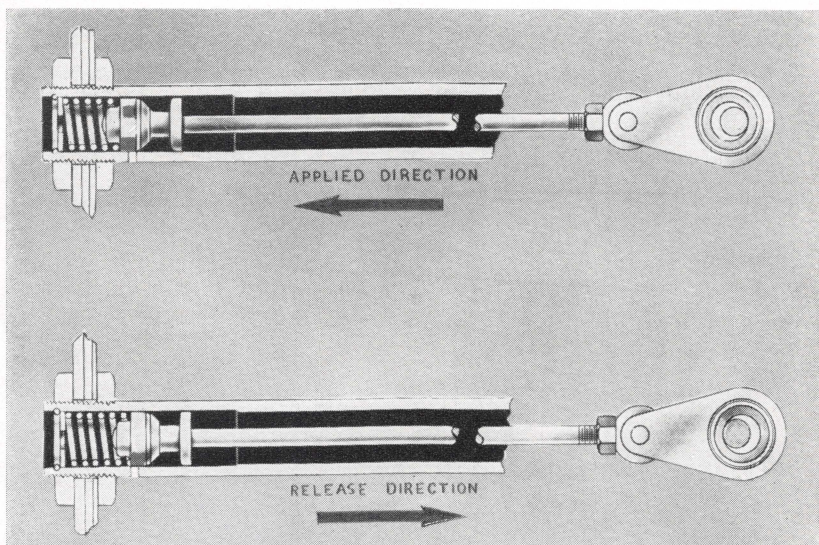
The follow-up action of internal valve cylinders might be compared to a boy leading a horse. As the boy tugs on the lead strap, the horse moves forward, but moves just far enough to



External and sectional view of an internal valve (Reactionary) power cylinder.



ease the tension on the bit, and stops again. As this operation would continue, we would have follow-up action; that is, a small force (from the boy) sets in action a "power" force, and the power force acts only to the point of catching up with the controlling motion.



Detail of the slide valve mechanism used in internal valve cylinders.

As an explanation of reactionary linkage, the following series of diagrams builds up the working elements, a step at a time, into the actual construction of this type linkage as used with internal valve cylinders.

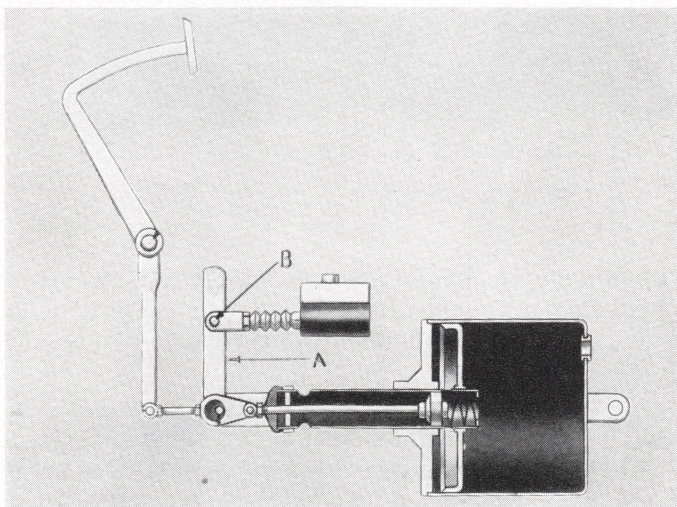


Diagram 1. In this and in the following two diagrams a theoretical system (not an actual installation) is shown to illustrate the reactionary principle.

Diagram 1. In a hook-up such as that shown in the preceding illustration, when force is first applied to the brake pedal, the valve rod opens the valve in the power cylinder. Movement of the piston then moves the lower end of lever A to the right. This causes lever A to rotate about axis B, but no force is exerted on the master cylinder to apply the brakes.

Diagram 2. Here the situation has been changed by adding fulcrum point C. Now, action of the power cylinder piston will apply the brakes. The reaction from the force

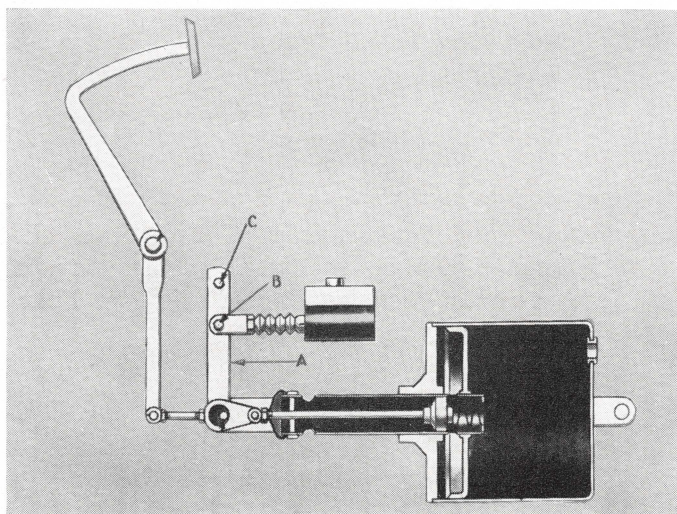


Diagram 2. A pivot point is provided for lever A.

exerted will be against fulcrum point C. In such a system, the brake control would be entirely by the position of the pedal; there would be no pedal "feel" within the range of the power of the cylinder.

Diagram 3. Now link D has been added, serving to feed back the reaction against pivot point C, to the brake pedal lever, and thus against the driver's foot. This reaction is in proportion to the force exerted by the cylinder but due to the lever ratios it is much smaller in amount.

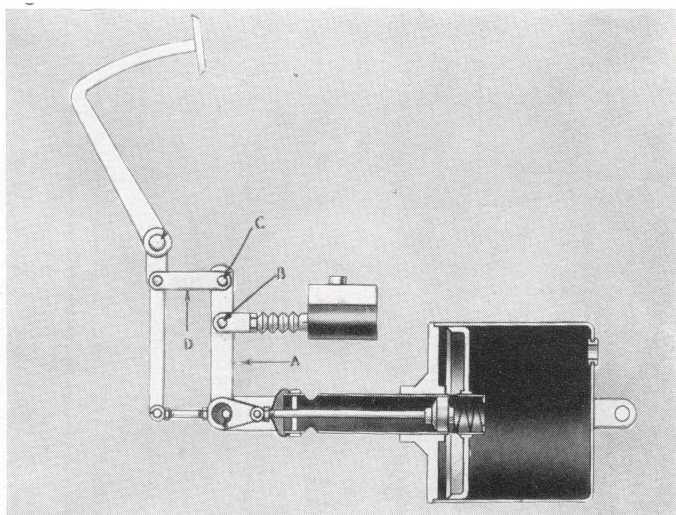


Diagram 3. The pivot point of lever A is linked to the brake pedal lever.

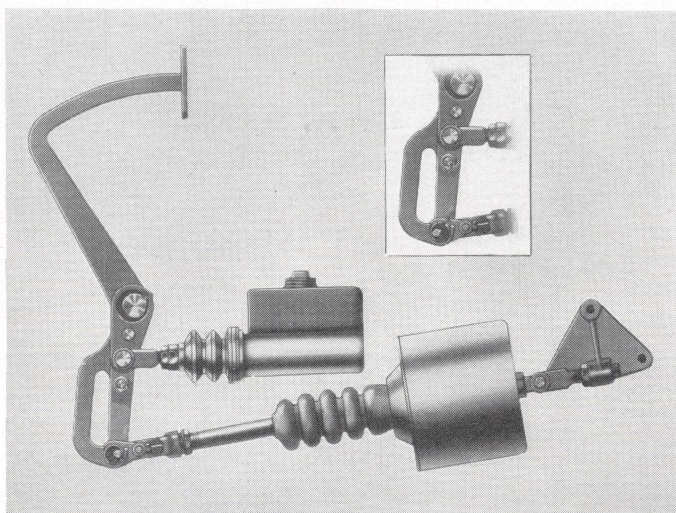


Diagram 4. Reactionary linkage as actually used.

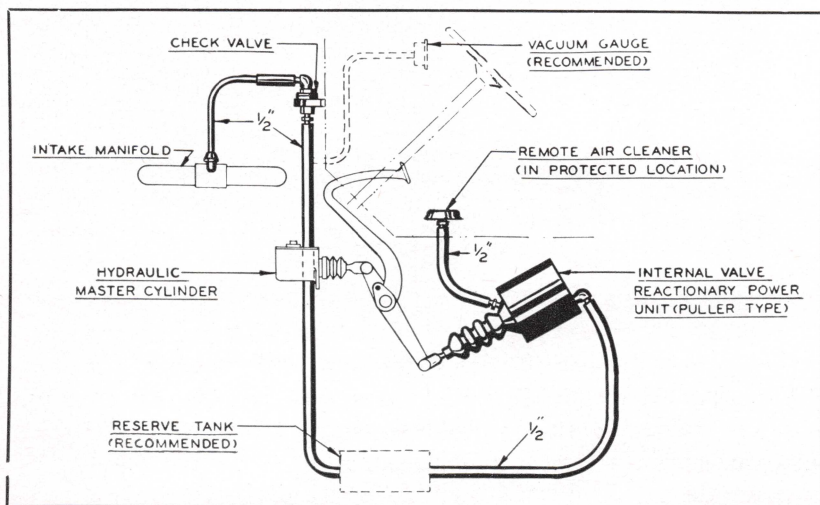
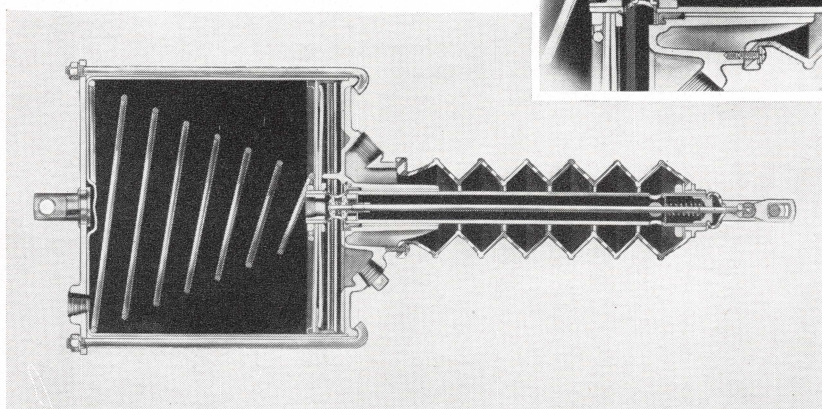
Diagram 4. Finally, this picture shows reactionary linkage as actually used, incorporating the principles illustrated in the foregoing diagrams.

Because internal valve cylinders are always used with reactionary linkage, these cylinders have come to be known as

“reactionary” cylinders, although it is apparent that the cylinder itself does not provide reactionary control, but is simply adapted for use with the necessary linkage for reactionary control.

Poppet Valve Internal Valve Cylinders

*Sectional views of a poppet valve internal valve cylinder.
Valve detail at right.*



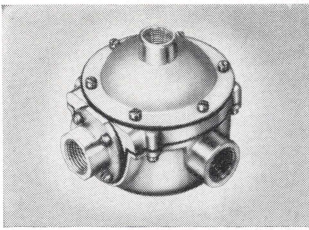
A typical truck installation using a reactionary cylinder.

Substituting a poppet type valve for the slide valve is a later development in reactionary cylinders for certain applications which improves the speed of brake action because of larger air passages and faster operating valves. Also, the poppet type valve is more positive in sealing action, therefore less likely to develop leaks after long use. Otherwise, poppet type cylinders operate on the same principles as the slide valve cylinders and are used with similar linkages.

CONSTRUCTION AND OPERATION OF B-K RELAYS (Trailer Valves)

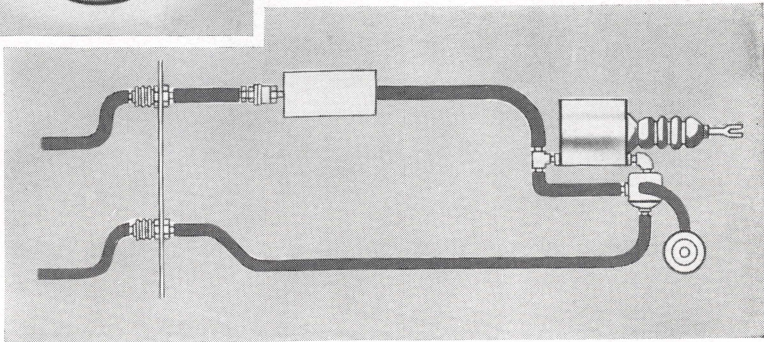
PR Relay

Vacuum Tractor to Vacuum Trailer



Left: PR Relay Valve.

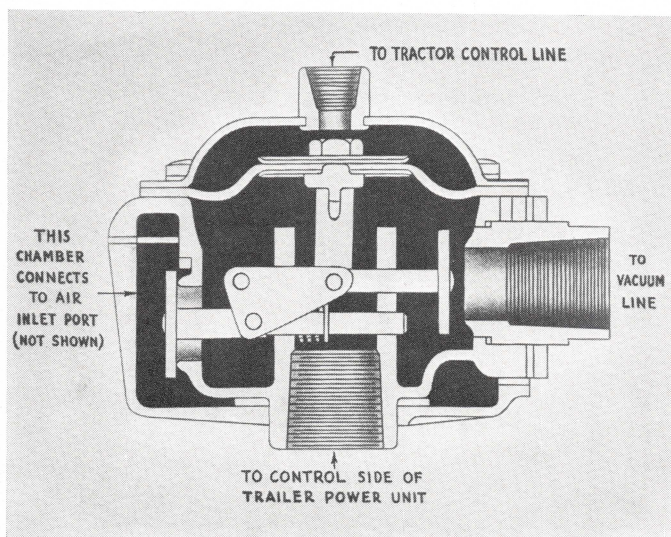
Below: Diagram of trailer installation showing connections to PR Relay.



The PR Relay is for use where both the tractor and the trailer are equipped with vacuum suspended systems. It is located on the trailer close to the trailer power unit and is controlled by a comparatively small volume of air through a control line from the tractor system. The relay itself has large area ports and quick-acting poppet valves for admitting air rapidly to the control side of the power unit for brake application, or for equalizing pressures on the piston for brake release.

The illustration below shows the working parts of the PR Valve; connections to other units in the system are indicated.

There are two poppet valves, one of which (shown at right) opens and closes the vacuum port; the other (shown at left) opens and closes the port which connects with outside air. These two valves are interconnected by means of the triangular-shaped linkage. This linkage, in combination with a coiled spring which tends to hold the atmospheric valve on its seat, causes one valve to close slightly before the other starts to open. This means that only one valve is open at a time.



Section through PR Relay, showing valves in position for released brakes.

The triangular linkage is controlled by a vertical yoke which extends upward and connects to the plate of a flexible air-tight diaphragm. This diaphragm separates the valve chamber into two compartments.

Valve Action. In the illustration, the vacuum valve is shown open and the atmospheric air valve is shown closed. This is the released position for the valves since the control side of the power cylinder is open to vacuum through the cylinder port at the bottom of the valve.

From this position, the first downward movement of the vertical yoke closes the vacuum valve. This brings the valves into the holding position since both valves are closed.

Further downward movement of the vertical yoke from the holding position opens the atmospheric valve which admits air to the control side of the cylinder and applies the brakes.

The Diaphragm. The compartment above the flexible diaphragm is connected to the control line from the tractor. The degree of vacuum above the diaphragm therefore always corresponds to the degree of vacuum in the control side of the tractor power cylinder. The degree of vacuum below the diaphragm, however, always corresponds to the degree of vacuum on the control side of the trailer power cylinder. If these two vacuums become unbalanced, the diaphragm moves either upward or downward and in so doing, operates the valves through the vertical yoke and triangular linkage.

The released position as illustrated would indicate that full vacuum is on the top side of the diaphragm since this upper compartment is connected to the tractor control line. Likewise, system vacuum would be on the bottom side of the diaphragm because the lower compartment is connected to vacuum.

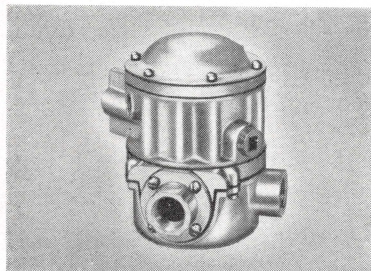
When brakes are applied on the tractor, air is admitted to the upper compartment through the control line. This air pressure forces the diaphragm downward, closing the vacuum valve and opening the air valve, thus applying the trailer brakes. The air valve will continue open until pressures between the upper and lower compartments are equalized; at this balancing point, the valves assume the holding position.

In short, the relay operates to keep the pressures on the control side of the tractor cylinder and on the control side of the trailer cylinder exactly balanced, which results in equal brake application on the two vehicles. Any momentary unbalance actuates the diaphragm and operates the valves to restore balanced pressures.

NOTE: In some original equipment installations of the PR Valve, a spring is provided around the vertical yoke, serving to press the diaphragm upward and in that way load the valve slightly in the released position.

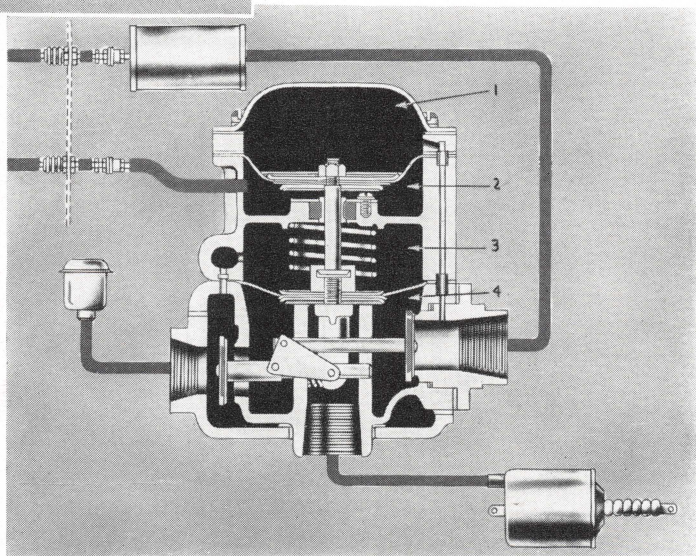
Conversion Relay

Vacuum Suspended Tractor to Atmospheric Suspended Trailer



Left: Conversion Relay (B-K type PC Valve).

Below: The internal working parts of the Conversion Relay with connections to other units shown diagrammatically. Valves are in released position.



The Conversion Relay serves the same purpose as the PR Relay but is for use on atmospheric suspended trailers which must work in combination with vacuum suspended tractors. From the above illustration, the interconnected valve mechanism with vertical yoke, will be recognized as identical with the PR Relay previously described. There are, however, two separate diaphragm chambers in the Conversion Relay, each chamber being divided into an upper and lower compartment by a flexible diaphragm.

The top diaphragm chamber may be considered a miniature vacuum suspended power unit of the diaphragm type. The upper compartment (1) is the constant vacuum side and is connected to vacuum through the passage shown in the illustration. The lower compartment (2) is the control side and is connected to the control line running from the tractor system. Therefore, this miniature power unit is always under the same vacuum conditions on both sides of the diaphragm as exist in the vacuum suspended tractor power unit.

The bottom diaphragm chamber also may be considered a miniature power unit, but of the atmospheric suspended type. The upper compartment (3) is always connected to atmosphere through the passage shown in the illustration. The lower compartment (4) containing the valves, also is connected to the vacuum side of the atmospheric suspended power cylinder of the trailer.

The valves in the illustration are shown in the released position. Balanced vacuum is on both sides of the top diaphragm; therefore, the top diaphragm exerts no force on the vertical stem and yoke. The bottom diaphragm is subject to atmospheric pressure on both sides and therefore exerts no pull, but it is held down by the coiled spring, holding the valves in the released position (atmospheric valve open, vacuum valve closed). In this position, the trailer power cylinder is suspended between equal atmospheric pressures and the brakes are released.

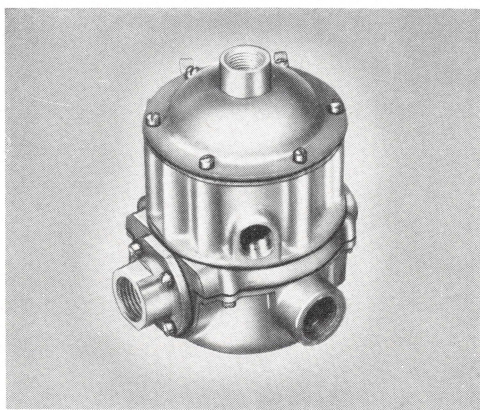
When the tractor brakes are applied, air enters the lower compartment (2) of the top diaphragm chamber through the control line from the tractor. This causes the vertical stem and yoke to pull upward on the valve linkage. When this happens, first the air valve is closed and then the vacuum valve is opened. Vacuum is thus admitted to the trailer power cylinder and continues to be admitted until the pull downward on the vertical stem and yoke from the lower diaphragm is exactly

equal to the pull upward exerted by the top diaphragm. At this point of balanced pull between the two opposed miniature power units, the valves are brought into holding position.

The principle of this valve therefore will be seen to be that of two miniature power units arranged to pull against each other. Pressure conditions in the one unit are identical with the tractor power cylinder. Pressure conditions in the other unit are identical with the trailer power cylinder. The result is that both the tractor and the trailer power cylinders are always applied to the same degree even though one power cylinder is of the vacuum suspended type and the other is of the atmospheric suspended type.

Universal Relay

Atmospheric Suspended Tractor to Atmospheric Suspended Trailer



Universal Relay (B-K type PUR Valve).

When it is desired to connect a tractor and trailer both of which have atmospheric suspended systems, the Universal Relay is used. Referring to the illustration on page 84, note that the Universal Relay is a two-diaphragm valve with valves and inter-connecting linkage similar to the PR. The upper diaphragm has a larger plate than the lower one and therefore has a larger effective area for air pressure to act upon.

Both sides of the top diaphragm, compartments (1) and (2), are under equal vacuums for normal operation; therefore, the top diaphragm chamber normally does no work; it is for use only in the event of break-away, discussed later.

The upper compartment of the bottom diaphragm chamber (3) is connected to the control line from the tractor. When atmospheric pressure is in the control line and therefore in upper compartment (3), the diaphragm is balanced between equal atmospheric pressures and exerts no push or pull on the valve linkage. Under this condition, the spring holds the vertical valve yoke down and holds the valves in released position; that is, air valve open, vacuum valve closed.

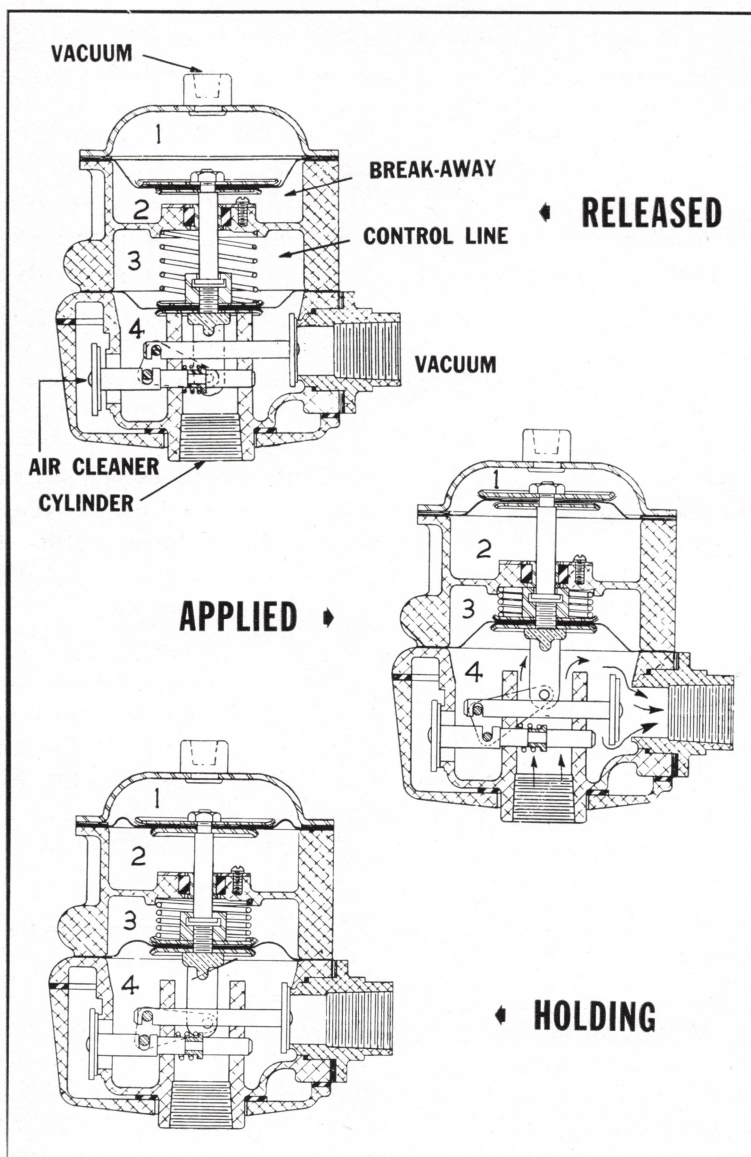
When the tractor brakes are applied, vacuum is in the control line and therefore compartment (3) is under vacuum. This causes the diaphragm to rise, and in so doing it closes the atmospheric valve and opens the vacuum valve, applying the trailer brakes.

Holding position is reached when the vacuum in compartment (4) equals the vacuum in compartment (3); at this point, the diaphragm balances at the midway or lapped position.

The effect of the Universal Relay is to maintain the same degree of vacuum in both the tractor cylinder and in the trailer cylinder, and therefore to apply the brakes equally on both vehicles.

Automatic Brake Application. Compartment (2) below the top diaphragm is connected into the vacuum line just ahead of the check valve, whereas compartment (1) is connected behind the check valve and consequently always has reservoir vacuum. When break-away occurs, air rushes into compartment (2), forces the diaphragm upward, and applies the brakes.

As the brakes are applied, vacuum increases in compartment (4) which opposes the effect of air pressure in compartment (2), but since the upper diaphragm is larger in area, its effective force is greater and the valves are held applied.



The three valve positions of the Universal Relay on an atmospheric suspended trailer controlled from an atmospheric suspended tractor.

Universal Relay

Atmospheric Suspended Tractor to Vacuum Suspended Trailer

When an atmospheric suspended tractor system is to operate with a vacuum suspended trailer, the Universal Relay also is used. Its connections and operation for this purpose, however, are quite different.

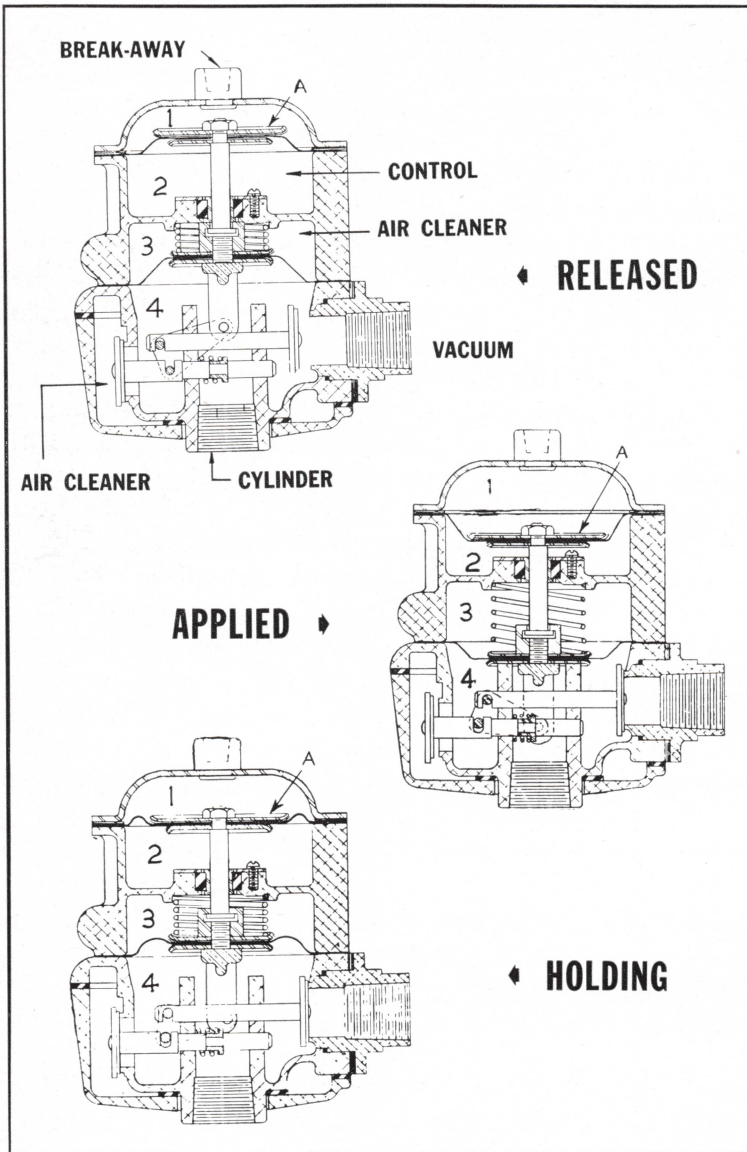
Referring to the illustration on the next page, compartment (2) is connected to the control line, and compartment (1) is connected to the vacuum line just ahead of the check valve.

Released. When the tractor brakes are released, atmospheric pressure is in the control line and therefore in compartment (2). This exerts upward pressure on the top diaphragm. Compartment (3), however, is also subject to atmospheric pressure, exerting a downward pressure on the bottom diaphragm. Due to the larger effective area of the top diaphragm, the vertical stem and yoke are forced upward, holding the air valve closed and the vacuum valve open. Since the trailer cylinder is vacuum suspended, vacuum in the control side of the cylinder causes the brakes to be released.

Applied. When the tractor brakes are applied, compartment (2) is subject to vacuum which balances the vacuums on either side of the top diaphragm. This allows atmospheric pressure in compartment (3), aided by the spring, to force the vertical stem and yoke downward, closing the vacuum valve and opening the air valve. Atmospheric pressure on the control side of the trailer power cylinder causes the brakes to be applied.

Holding. Holding position is reached when the upward pull from the top diaphragm is balanced by the downward pull from the lower diaphragm.

Automatic Brake Application. Compartment (1) is connected to the vacuum line just ahead of the check valve. When the vehicles break apart, air rushes into compartment (1), balancing the top diaphragm between equal atmospheric pressures. This allows atmospheric pressure to force the bottom diaphragm downward, aided by the spring, against vacuum in compartment (4). The result is that the vacuum valve is closed and the atmospheric valve is opened, which applies the trailer brakes.

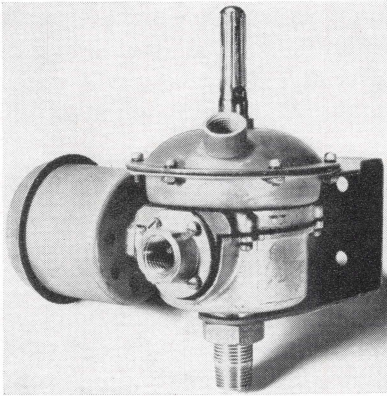


Three valve positions of the Universal Relay on a vacuum suspended trailer controlled from an atmospheric suspended tractor.

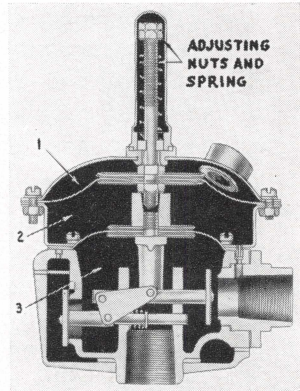
RELAY VALVES USED ON TRACTORS

The following valves are used on tractors, but are similar in construction and operation to the trailer relay valves previously described.

Synchronizer Valve



Synchronizer Valve. (B-K type PS Valve) with air cleaner attached.



Section through Synchronizer Valve (valves in released position).

It is important that the trailer brakes do not lag behind the tractor brakes either in time or force of application, otherwise the trailer tends to run up on the tractor. Sometimes, however, vehicles must work together having braking systems which are inherently out of balance with each other. For example, the tractor might be equipped with hydraulic servo-action brakes, requiring minimum actuating force for a given braking effect; the trailer on the other hand, might have non-servo mechanical brakes requiring a comparatively great actuating force for a given braking effect. The combination of these two vehicles would tend to produce a train in which the tractor brakes would exert greater force throughout the braking range than the trailer brakes. Other than the matter of safe control, such trains are uneconomical to operate because one vehicle does more than its share of braking and is subject to rapid brake lining wear and abnormally high brake maintenance expense.

To permit balancing the braking systems of two such vehicles, a special type valve is available called a Synchronizer. This valve has an adjustment which allows balancing the relative brake performance of the two vehicles.

Because the conditions which make the Synchronizer necessary are usually inherent in the tractor braking system, this unit is installed on the tractor.

The Synchronizer is for use on a vacuum suspended tractor system in combination with a vacuum suspended trailer. The use of a Conversion Valve on the trailer, however, will allow combination of a Synchronizer-equipped tractor with an atmospheric suspended trailer.

The foregoing illustration shows a section through the Synchronizer which has the familiar arrangement of two poppet valves with interconnecting linkage operated by a vertical yoke. In this valve, however, the valve chamber is separated into three compartments by two flexible diaphragms. The vertical diaphragm stem extends upward and is subject to the control of a coiled spring. The spring tension is adjustable by means of the nut and lock nut. The adjusting stem is enclosed by an air-tight cap to prevent possible leakage past the stem.

Compartment (1) is connected to the control line from the tractor; compartment (2) is under constant vacuum; compartment (3) connects to the trailer control line through the bottom port.

Released. When the tractor brakes are released, the same degree of vacuum exists in the three compartments, and both diaphragms are balanced. In this position, the spring holds the valves in released position (vacuum in the trailer control line).

Applied. When tractor brakes are applied, air is admitted to compartment (1) and forces the diaphragm downward. This closes the vacuum valve and opens the atmospheric valve, thus applying trailer brakes.

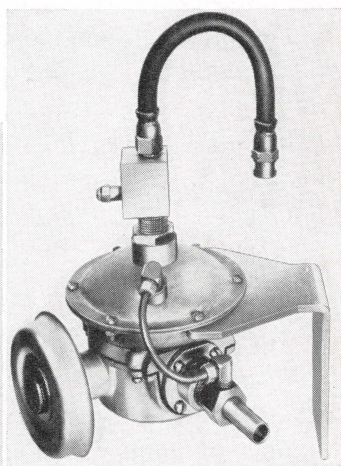
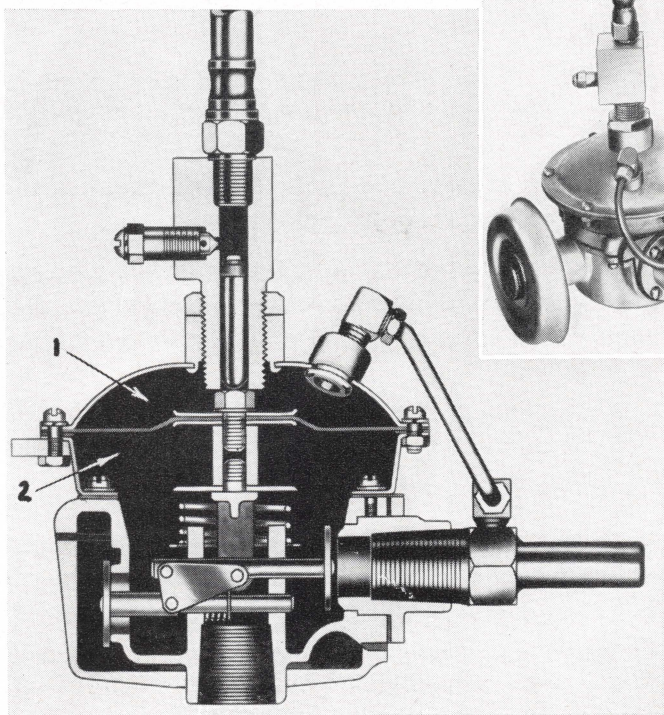
Holding. When the pressure in compartments (1) and (3) are equal, the valve balances in the holding position.

The upper diaphragm has a larger plate and therefore a larger effective area than the lower diaphragm. Without the spring action, this difference in plate area would favor trailer brake application. The spring counteracts this difference in diaphragm area and since the spring tension is adjustable, the ratio of tractor brakes to trailer brakes can be adjusted.

Hydraulic Relay

Right: Hydraulic Relay (B-K type HR Valve).

Below: Section through Hydraulic Relay.



The Hydraulic Relay provides means of operating trailer brakes from the hydraulic line pressure of the tractor braking system.

The Hydraulic Relay is designed to control a vacuum suspended trailer system. It may be used with an atmospheric suspended trailer system, however, by installing a Conversion Valve on the trailer.

The valve chamber is divided into two compartments by an air-tight flexible diaphragm. This diaphragm operates the valve mechanism through a vertical yoke and triangular linkage similar to other B-K relays. Above the diaphragm there is a hydraulic cylinder and plunger. The plunger of this hydraulic cylinder bears upon the top of the diaphragm assembly.

The compartment above the diaphragm (1) is under constant vacuum. The compartment below the diaphragm (2) connects to the control line and thence to the control side of the trailer cylinder.

When the tractor brakes are released, the diaphragm is under balanced vacuum and is held in the upper or released position by the coiled spring. This spring exerts sufficient force to hold the valves in released position against the residual line pressure in the tractor hydraulic system.

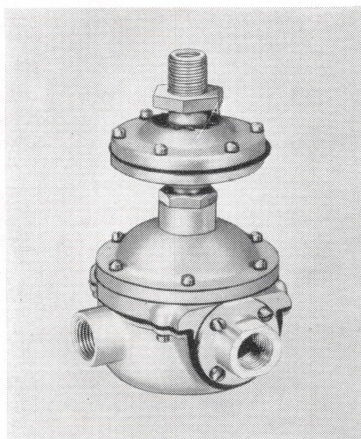
When the tractor brakes are applied, the hydraulic plunger forces the diaphragm assembly downward, which closes the vacuum valve and opens the air valve, thus applying the trailer brakes.

The upward force from the diaphragm builds up to the point of balancing the hydraulic pressure from the plunger and thus brings the valves into the holding position.

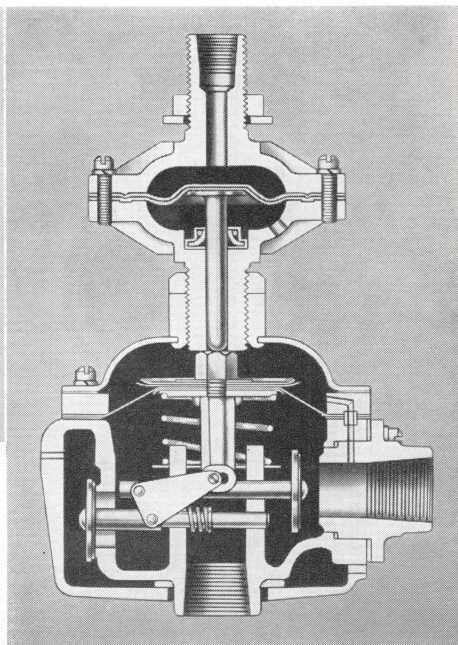
The Hydraulic Relay is usually furnished to give full graduation of trailer brakes with a hydraulic line pressure range up to 700 pounds per square inch. It may be obtained, however, equipped to graduate completely within a hydraulic pressure range up to 800 pounds per square inch*, for use on tractor hydraulic systems of higher maximum pressure.

*In both cases, the range of vacuum so graduated, is up to 17 inches of mercury. The valve will graduate a higher vacuum range but the hydraulic pressure will be correspondingly higher.

Pneumatic Relay



*Above: Pneumatic Relay
(B-K type PNU Valve).*



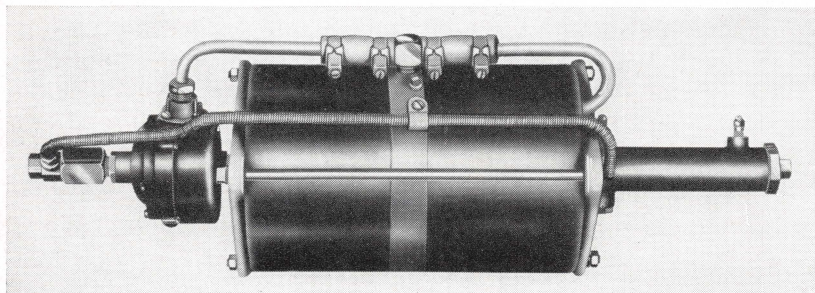
*Right: Section through the
Pneumatic Relay Valve.*

Vacuum-power trailer brakes can be operated from an air-brake equipped tractor by using the Pneumatic Relay Valve installed on the tractor. As air pressure in the tractor air brake system increases, a decrease of vacuum in the trailer control line applies the trailer brakes in exact proportion to the tractor brakes.

Reference to the sectional illustration above shows an arrangement similar to the Hydraulic Relay, except a pneumatic diaphragm unit takes the place of the hydraulic cylinder.

Air pressure from the tractor air-brake system acting upon the upper diaphragm forces the plunger against the lower diaphragm assembly. Downward movement of the lower diaphragm operates the valves to apply the trailer brakes. As air pressure builds up in the lower valve compartment, the lower diaphragm presses upward until the upward force balances the downward force from the upper diaphragm at which point the valves are brought into the holding position.

HYDROVAC



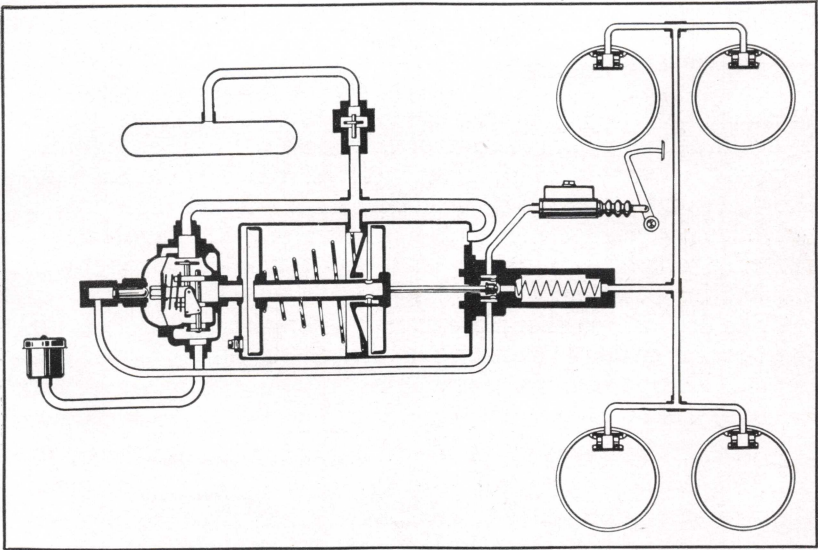
Hydrovac Unit.

Hydrovac is the trade name for a B-K “one-unit” vacuum power braking system for use on trucks, tractors or buses equipped with hydraulically actuated brakes. It combines into one compact assembly a hydraulically actuated control valve, a tandem-piston power cylinder and a hydraulic cylinder. The assembly is a complete self contained vacuum power brake “system” which eliminates the need for external levers or linkage. Connections to the vehicle braking system are entirely hydraulic, consisting of a line from the vehicle brake system master cylinder to the Hydrovac, and a hydraulic line from the Hydrovac connecting to the wheel cylinders of the vehicle brake system. Contrasted with conventional vacuum power brake systems, the Hydrovac is connected *hydraulically* instead of mechanically, both to the brake pedal and to the brake units at the vehicle wheels.

Among the advantages which make Hydrovac an important development in vacuum power braking are:

- Simplified installations.
- External levers and links eliminated.
- Unlimited latitude for location of the Hydrovac.*
- Combined physical actuation with power braking as in other B-K systems.
- Unimpaired physical actuation in event the power system fails due to accidental damage or other cause.

*Someone waggishly remarked that, with long enough hoses, the Hydrovac could be “held on the driver’s lap” and still work!



Diagrammatic section through the Hydrovac (released position).

The diagrammatic sectional view above shows the inside working parts of the Hydrovac. From this picture it is easy to distinguish the three basic units; namely, the power cylinder, the control valve (left) and the hydraulic cylinder (right).

NOTE: For complete service data see "Servicing The Bendix Hydrovac" Form 9-227A.

The Power Cylinder

The power cylinder of the Hydrovac is divided into two equal compartments,* each of which is provided with a piston. The two pistons work on the piston rod so that the effect is that of two cylinders placed end-to-end with pistons connected in tandem.

This arrangement gives double the effective piston area and consequently twice the pull of a single cylinder of the same diameter. Each cylinder compartment is provided with the necessary seals and air passages to operate on the vacuum suspended principle.

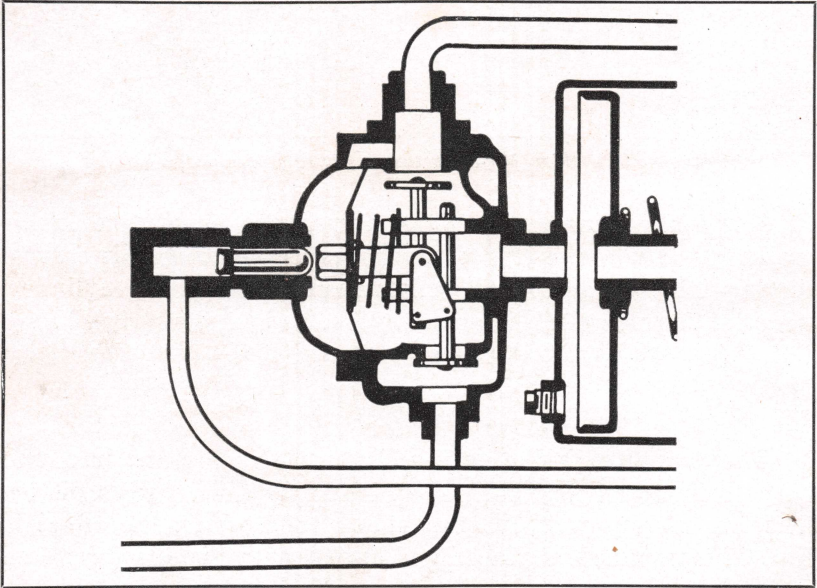
A helical spring serves to return the pistons to released position when the air pressures on both sides of each piston are balanced.

*Certain Hydrovac installations which require less power, use a design with only one cylinder and piston; otherwise these units work as described.

Control Valve

The operating principle of the control valve is the same as that previously described for the Hydraulic Relay. Hydraulic pressure from the master cylinder of the vehicle acts upon the hydraulic plunger in the control valve and forces the diaphragm toward the valves. This movement of the diaphragm moves the valves into the applied position. As air is admitted into the valve compartment below the diaphragm, the diaphragm is forced against the plunger until the valves are brought into the holding position.

The diaphragm therefore exerts a reactionary force against the plunger which is exactly proportional to the degree of brake application. This reactionary force not only brings the valves

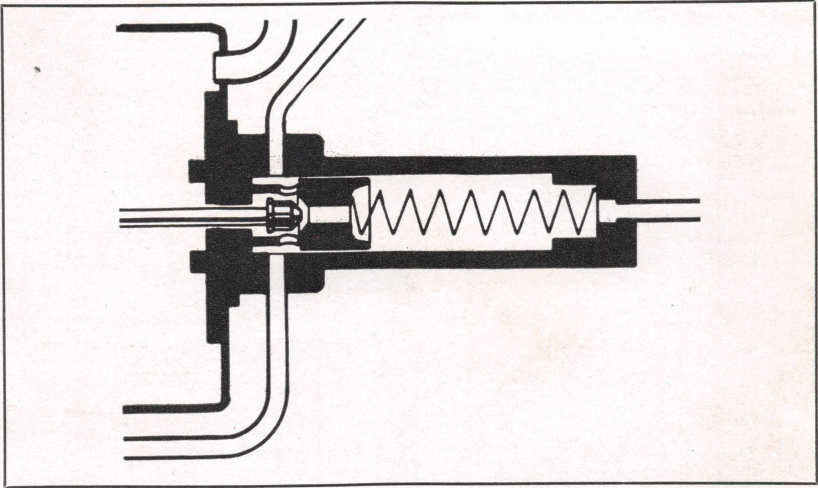


Diagrammatic section through the hydraulically actuated control valve.

into the holding position but it is hydraulically transmitted to the foot pedal to give pedal feel or reactionary control.

Hydraulic Cylinder

The hydraulic cylinder of the Hydrovac unit is provided with a rubber cup and piston similar to the vehicle master cylinder. The piston rod from the power cylinder forces this piston and cup into the hydraulic cylinder. In that way, fluid is forced to the vehicle wheel cylinders to apply the brakes.



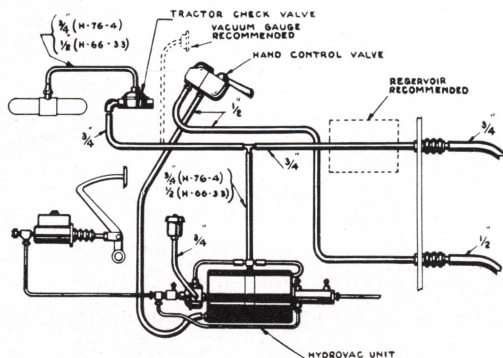
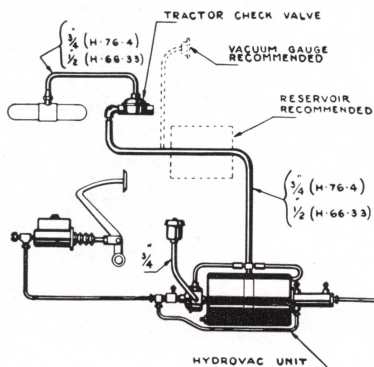
Sectional through hydraulic cylinder showing valve mechanism.

The end of the piston rod fits into a tapered valve which seats against the hydraulic piston. A passage through the hydraulic piston allows fluid to pass through when the valve is off the seat, that is, when the power cylinder pistons are in released position.

When the driver first steps upon the brake pedal, the passage through the hydraulic piston is open because the power cylinder pistons are in released position. As hydraulic pressure builds up, the control valves move into applied position, causing the power cylinder pistons to act. The first movement of the piston rod closes the passage through the hydraulic piston; further movement in the applied direction forces the hydraulic piston into the cylinder and thus applies the brakes. Note that during brake application the hydraulic force from the vehicle master cylinder, necessary to operate the control valve, is automatically added to the force of brake application, since it also acts upon the Hydrovac hydraulic piston.

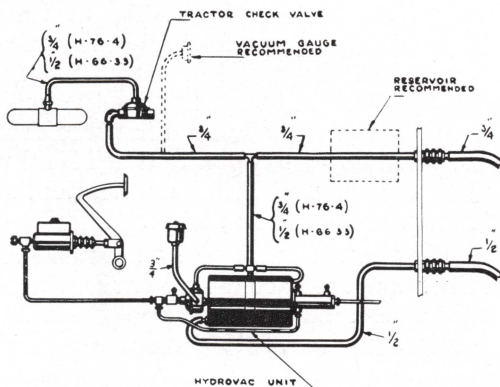
Should the vacuum system become inoperative due to damaged lines or other accidental cause, the power cylinder pistons return to released position and the vehicle hydraulic system automatically returns to physical operation. Under this condition the power cylinder pistons remain at rest; the hydraulic fluid flows through the hydraulic piston and to the wheel cylinders. Therefore, there is no drag on the physical braking system.

Truck installation. The hydraulic line from the Hydrovac runs to the vehicle wheel cylinders.

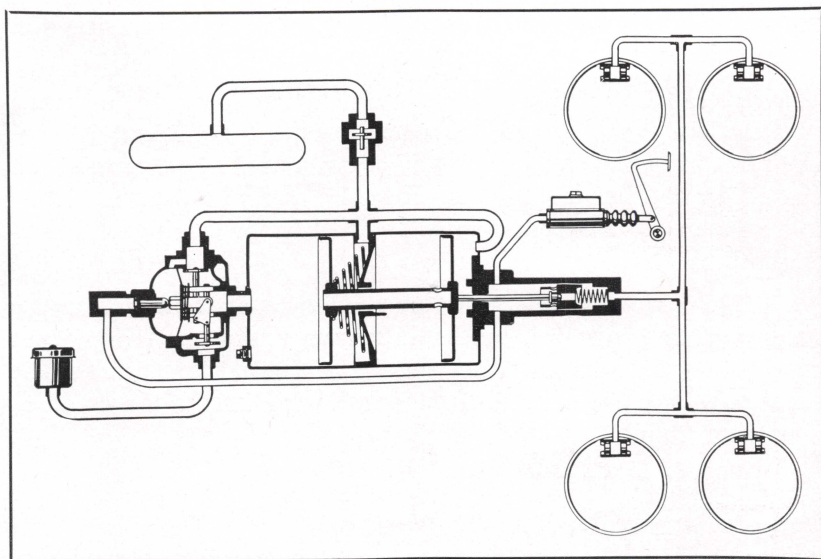


Tractor installation with independent hand control of trailer brakes. The foot pedal operates both tractor and trailer brakes. The hydraulic line from the Hydrovac runs to the tractor wheel cylinders.

Tractor installation. The hydraulic line from the Hydrovac runs to the tractor wheel cylinders. Vacuum connections control the trailer vacuum system.

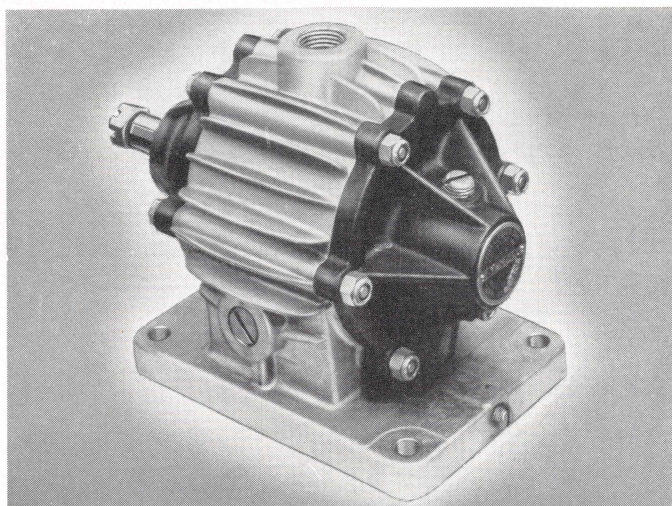


Diagrams of three typical Hydrovac installations.



Hydrovac in applied position.

CONVAC VACUUM PUMP



B-K Convac Vacuum Pump.

On vehicles with Diesel type engines, the need arises for an independent source of vacuum since such engines lack the natu-

ral source that exists in the intake manifold of gasoline engines.

Also, vacuum pumps are sometimes installed on large, heavily loaded gasoline-powered vehicles as a means for extra brake power when the nature of the service is unusually severe, such as long pulls through traffic or on mountainous roads. In such uses the pump serves to maintain maximum vacuum during periods of frequent brake application or during long up-grade pulls.

To provide a source of vacuum for such installations, a rotary vacuum pump is available known under the trade name of the Convac Pump. Other details of the system remain the same whether the source of vacuum is the intake manifold or a vacuum pump.

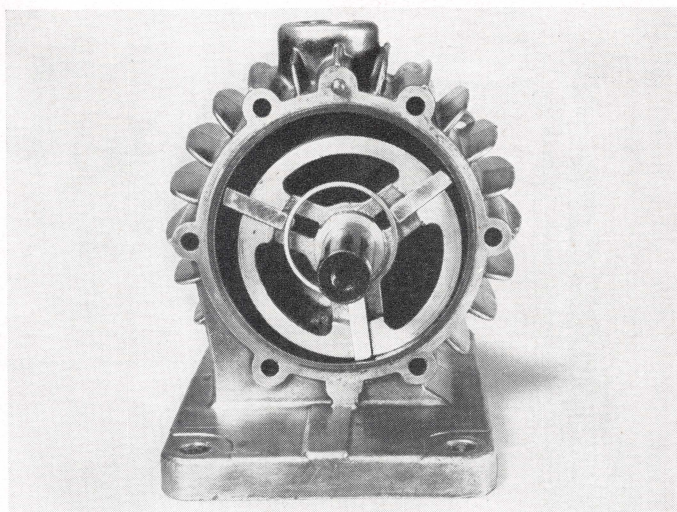
How the Convac Pump Works

The body of the Convac Pump provides a closed cylindrical chamber. Inside this cylindrical chamber, a rotor turns on an axis which is offset or eccentric with the axis of the cylinder. Three vanes are provided in the rotor, mounted so that they follow the surface of the cylinder bore. These vanes divide the space between the rotor and the cylinder bore into three air-tight compartments. As the rotor turns, the volume of each of these three compartments increases and decreases due to the eccentric position of the rotor. An inlet port is provided so that air is drawn into each of the three compartments during the part of the turn where their volume is increasing; an outlet port is provided through which air is expelled as the compartments decrease in volume. The result is that a high vacuum is created on the inlet side of the pump, (about 28" of mercury at sea level).

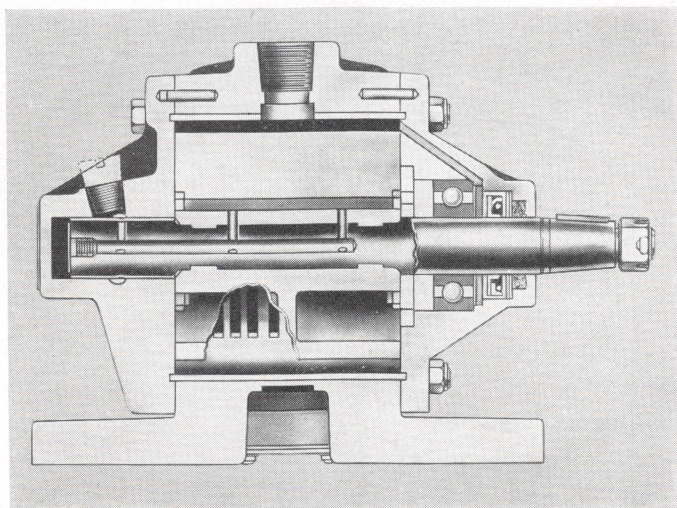
Lubrication

The Convac Pump is furnished for two different types of lubrication: (1) lubrication from the engine crankcase supply of oil; (2) lubrication from a separate oil reservoir.

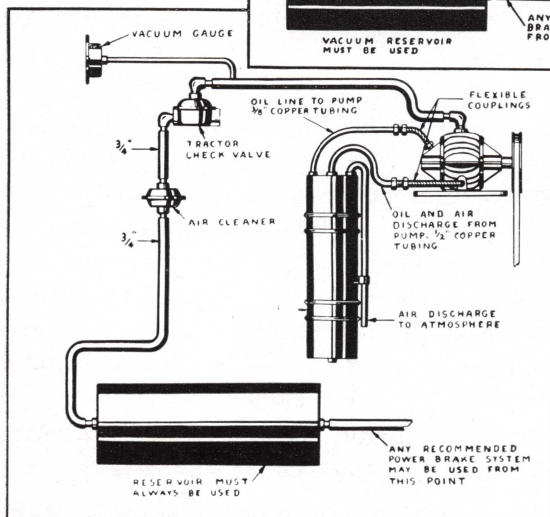
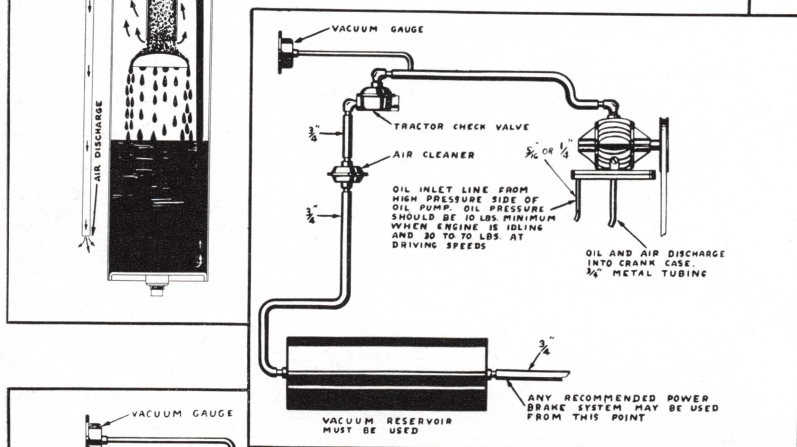
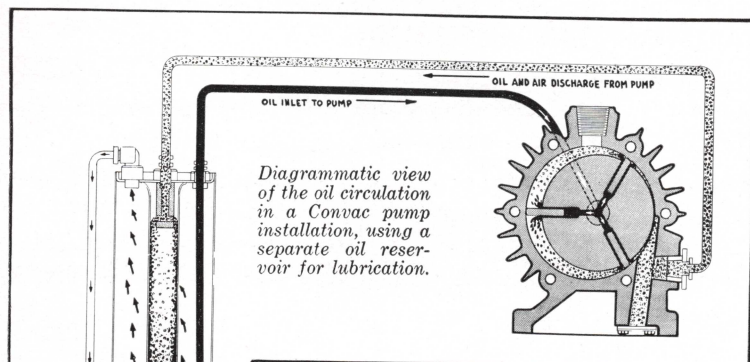
The simpler system lubricates the pump through an oil line from the engine pressure system. This oil is expelled from



Convac pump with end plate removed to show rotor and vanes.



Longitudinal section through Convac pump.



Above: Diagram for Convac installation, using oil from the crankcase for lubrication.

Left: Installation diagram for a Convac pump, using a separate oil reservoir for lubrication.

the pump outlet, usually into the engine breather pipe and thus is returned to the engine crankcase.

Crankcase oil is subject to a certain amount of dilution and carbon accumulation, so that a separate oil supply for the Convac Pump is desirable, particularly on Diesel engines.

This type system is provided with an oil reservoir from which oil is drawn into the pump on the vacuum side. Air from the pump outlet is exhausted into the reservoir which is provided with an air space and baffle plate to allow the air and oil to separate.

VACUUM HOSE

The vacuum lines connecting the various units of the vacuum power brake system are combinations of lengths of copper tubing and of flexible rubber hose. The flexible hose is necessary where the units must move with relation to each other, as in the connections to the control valve; likewise, flexible hose is used where vibration occurs between units as in connections from sprung to unsprung parts.

Rubber hose used for vacuum lines is subject to the peculiar conditions of low pressure inside and higher pressure outside. This is exactly the opposite of what is ordinarily encountered, since hose usually holds a higher internal pressure against outside atmospheric pressure.

The vacuum hose therefore is subject to collapse from outside pressure and must be especially made to withstand this; at the same time, it must have sufficient body to resist kinking or collapsing when sharply curved. Moreover, the inside surface of the vacuum brake hose is subject to the action of a certain amount of gasoline and oil vapor which finds its way into the system. For this reason, ordinary rubber is not suitable for this inside surface since rubber is affected by gasoline and oil, and would eventually cause obstructions.

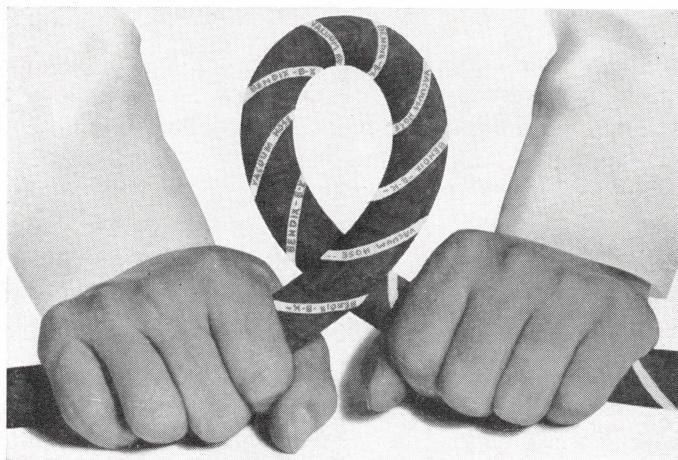
It is also true that the outside surface of vacuum brake hose must stand exceptionally rough usage and wear.

It is apparent that ordinary hose is not suitable for vacuum power brake installations. Its use is likely to lead to brake

failure due to obstructed lines; moreover, inferior hose requires frequent replacement which makes the best quality hose the cheapest in the long run.

B-K Vacuum Hose is made specifically for vacuum power brake use. It has ample strength and body to resist outside pressure and allow short bends without kinking. The inner tube is of special composition to resist gasoline and oil without danger of restrictions due to deterioration. The outer covering is of tough wear-resisting rubber ideally suited for long service under severe conditions.

So that genuine B-K Hose can be quickly distinguished from ordinary hose, it is distinctively marked with a red spiral label.



*B-K Hose sharply curved to demonstrate.
resistance to kinking.*

POWER BRAKES VS. "BOOSTERS"

When vacuum power brakes are used as an aid to physical braking rather than as a full power brake system, they are sometimes called "boosters." That is, if the system is so designed that the driver is called upon to exert a considerable pedal pressure and only the additional force required for full brake application is supplied by the power cylinder, then the

cylinder may be said to aid or "boost" a basically physical braking system. Such installations are cases of "physical brakes plus help from a power cylinder."

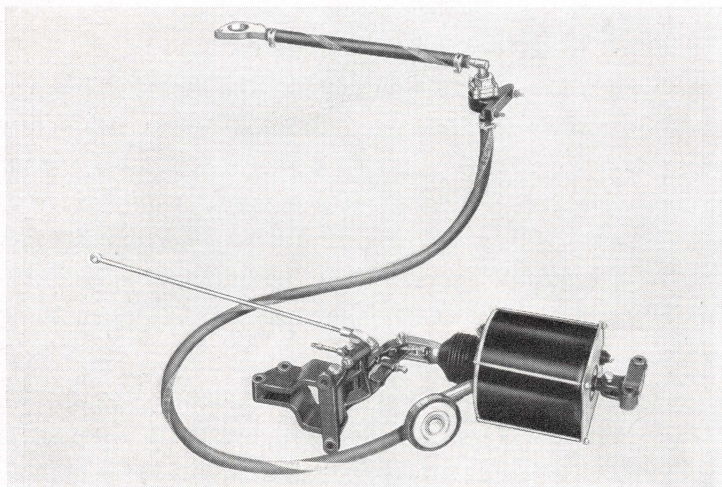
This type system is made possible by the fact that in vacuum brakes the driver's foot-power is automatically combined with the vacuum-power. Use of larger power cylinders correspondingly decreases the physical force necessary on any given class of installations. If the power cylinder is large enough to furnish all the required power, then the physical effort of the driver is practically limited to that necessary to open the control valve.

In actual installations, however, it is customary to proportion the system for a reasonable pedal pressure. In fact, it is well proved that an appreciable pedal pressure is safer and smoother in operation than an extremely light pedal. Moreover, there is some economy in the size of power brake units required if part of the braking force comes from the driver's foot.

It is nevertheless obviously incorrect to assume, because vacuum brakes can be installed as "boosters," that they are limited to being "boosters;" that is, that they cannot be made to work as full power brakes. As a matter of fact when vacuum brakes are used on trailers, no physical effort is involved and the vacuum power unit must be large enough to furnish all the braking force. Such trailer installations are necessarily one hundred per cent power; trucks and tractors can be given similar effects by the simple procedure of using power units large enough to give the necessary force for full brake application.

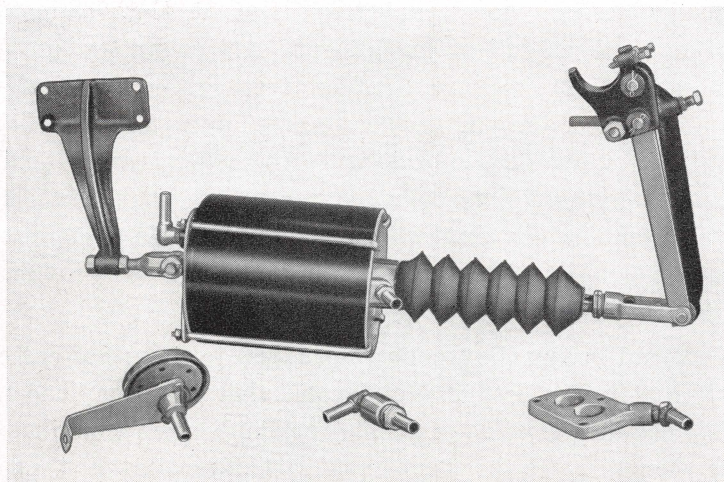
To avoid giving the wrong impression to those not entirely familiar with the facts, it is suggested that the term "booster" be dropped entirely. This avoids the implication that just because vacuum power brakes can be part physical, that they are limited to being only "boosters."

INSTALLATION KITS



Typical installation kit for Chevrolet.

Complete kits of necessary B-K units and fittings for various specific vehicle installations are available to the service field. These kits afford a quick and economical means of obtaining a complete vacuum power brake system. Listings of various kits available, are given in Bendix B-K Catalogs.



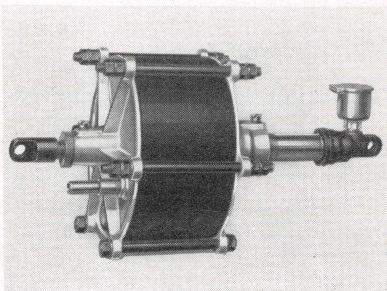
Typical installation kit for Ford.

IV OTHER B-K UNITS

The following B-K units are either older models which have been superseded by later units, or units which for other reasons are less frequently encountered in the service field. These units, therefore have not been included in the main body of this book, but for the sake of identification, they are briefly described and illustrated here.

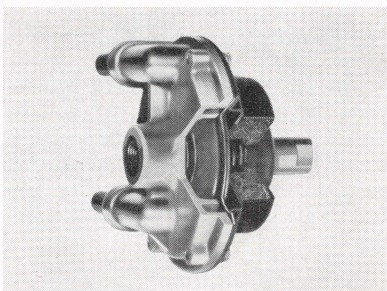
BNS, MB, DN, Power Cylinders

This earlier series of B-K Power Cylinders has poppet-type internal valves but is not used with reactionary linkage. The need of extensive service on these units would make replacement advisable, using current type power cylinders. For easy identification, note that the piston rod extends through both ends of the cylinder.



Q Control Valve

The Q Valve is used on atmospheric suspended systems, usually installed on light trucks and passenger cars. Within the valve housing, a flexible diaphragm forms the valve proper. This diaphragm fits against a seat from which it is lifted by action of the brake pedal to admit air or vacuum to the power cylinder.

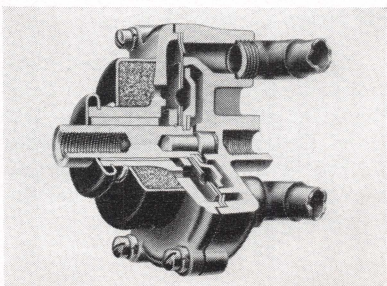


VA and AP Control Valves

The VA Valve is similar to the Q Valve in design and function except it is of larger capacity and was used on larger vehicles.

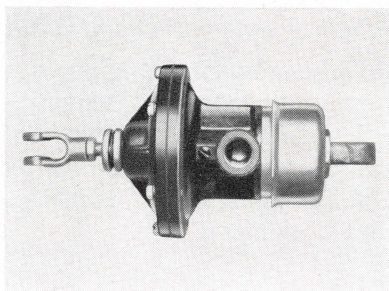
The AP Valve is identical with the VA except it is of the pusher type; that is, it is used where the applying force is compression instead of tension.

Both valves are for use on atmospheric suspended systems.



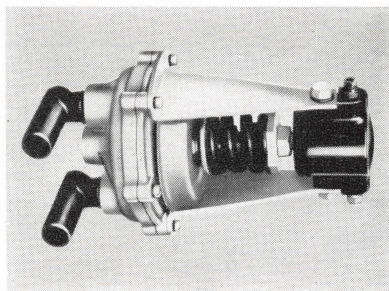
BEV Control Valve

This is a special control valve installed in combination with leverage systems. It combines a plunger type vacuum valve with a reactionary diaphragm. It is used principally as original factory equipment on certain passenger cars.



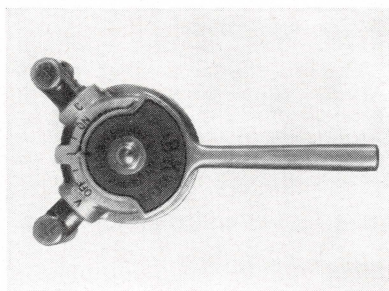
HVP Control Valve

The HVP Valve is a hydraulically operated control valve used on hydraulic brake tractors to operate trailer vacuum power brakes. Mechanically it consists of a hydraulic cylinder which operates a diaphragm-type vacuum valve.



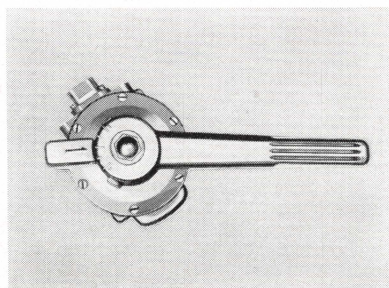
HB Hand Control Valve

The HB Valve is a hand control valve of earlier model. It will be found in use on both atmospheric suspended and vacuum suspended systems. The mechanism of the HB Valve is of the diaphragm type.



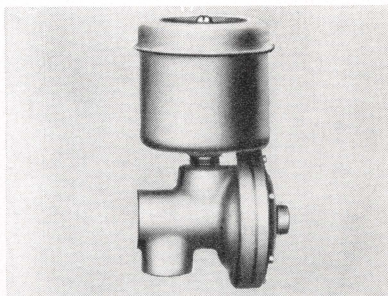
PH Hand Control Valve

The PH Valve is a hand control valve of later production than the HB, but earlier than the RH Hand Control Valve which is described in the main section of this book. In mechanical principle, the PH is a poppet type valve.



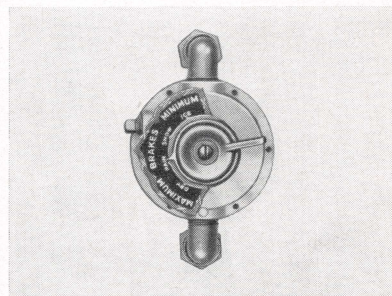
REV Relay Valve

This is an early production relay used on vacuum suspended trailers operating with vacuum suspended tractors. It consists of a plunger type vacuum valve controlled by a diaphragm. The unit shown at the top of the valve in the illustration is an air cleaner. The valve shown is the pneumatic REV; the plain REV is similar in appearance except the external tube and lever are omitted.



VAC Regulating Valve

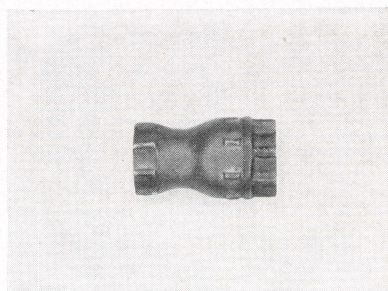
This valve, usually mounted on the instrument board, provides means of regulating the degree of power available from the vacuum power brake system. Its use allows adapting the braking system to road and load conditions, giving less braking force for light loads or slippery road surfaces.



VC and TC Check Valves

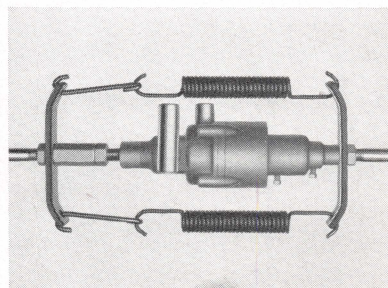
These two check valves are earlier production models, similar in use to present day VC and TC Valves. The poppet valve in these earlier models was not provided with resilient material inserts.

The VC is for use on trucks and tractors and does not have an internal spring; the TC is an emergency valve for trailers and has an internal spring.



Straddle Springs

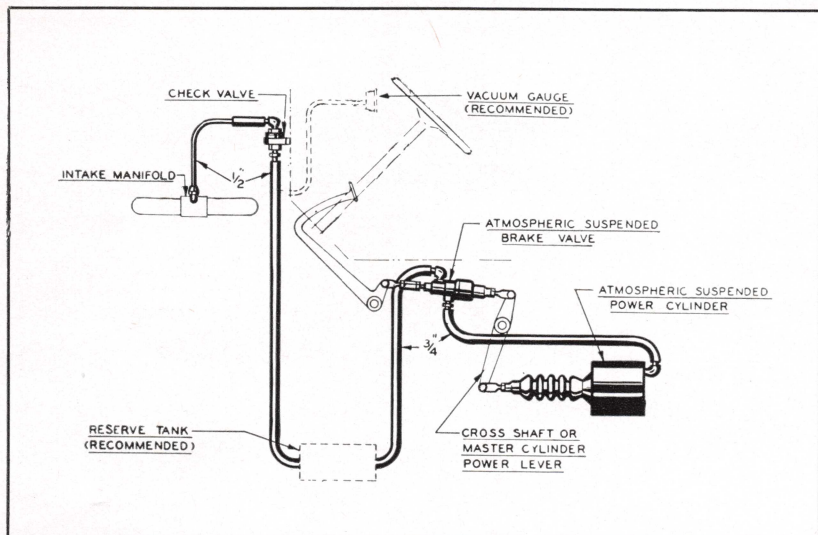
Straddle Springs are attached to the control valve to give extra spring loading to the valve. Their use has the effect of applying more physical effort to the tractor brakes before the power brake system begins to act. This increases the ratio of tractor brakes to trailer brakes for a given pedal pressure.



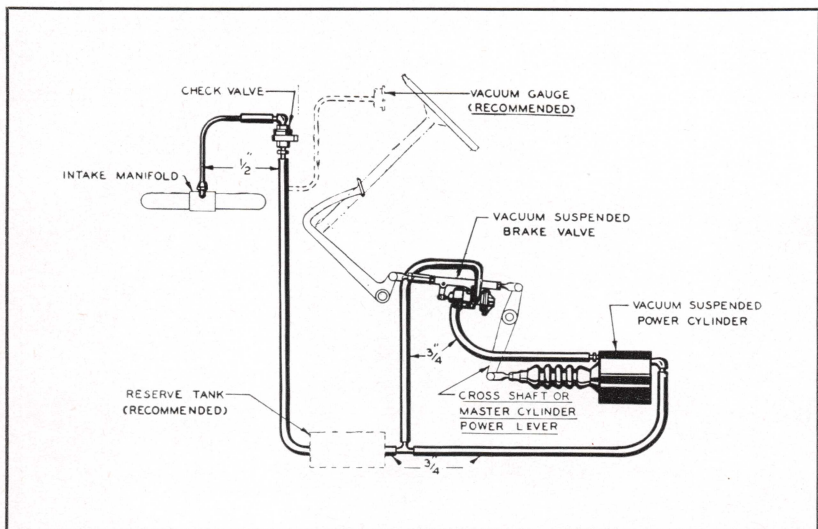
V. DIAGRAMS OF TYPICAL B-K INSTALLATIONS

								DIAGRAM NUMBERS
TRUCKS	-	-	-	-	-	-	-	1-7
TRACTORS	-	-	-	-	-	-	-	8-30
TRAILERS	-	-	-	-	-	-	-	31-34
VACUUM PUMP	-	-	-	-	-	-	-	35-36

TRUCK INSTALLATIONS

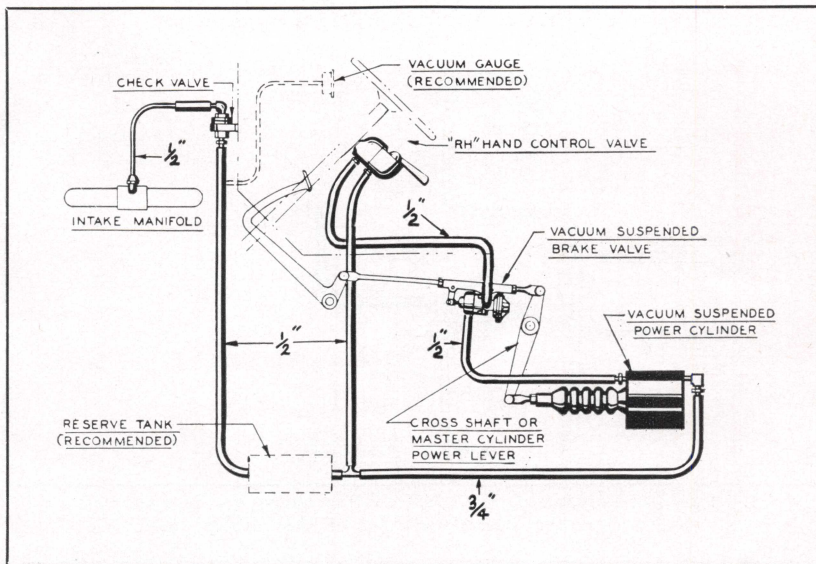


1. Atmospheric suspended truck installation.

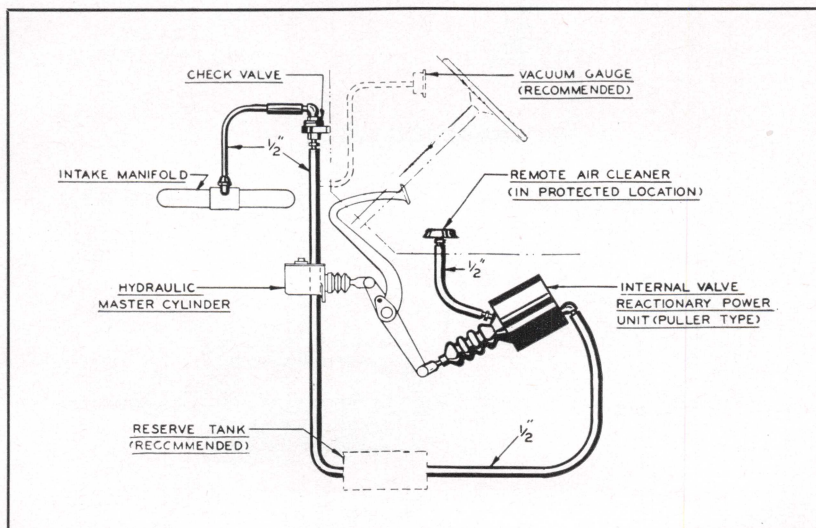


2. Vacuum suspended truck installation; RXL Reactionary Control Valve shown.

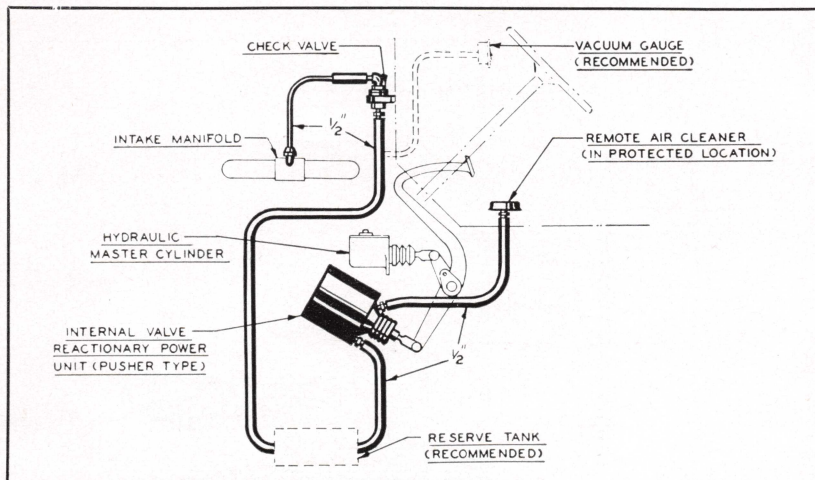
TYPICAL B-K INSTALLATIONS



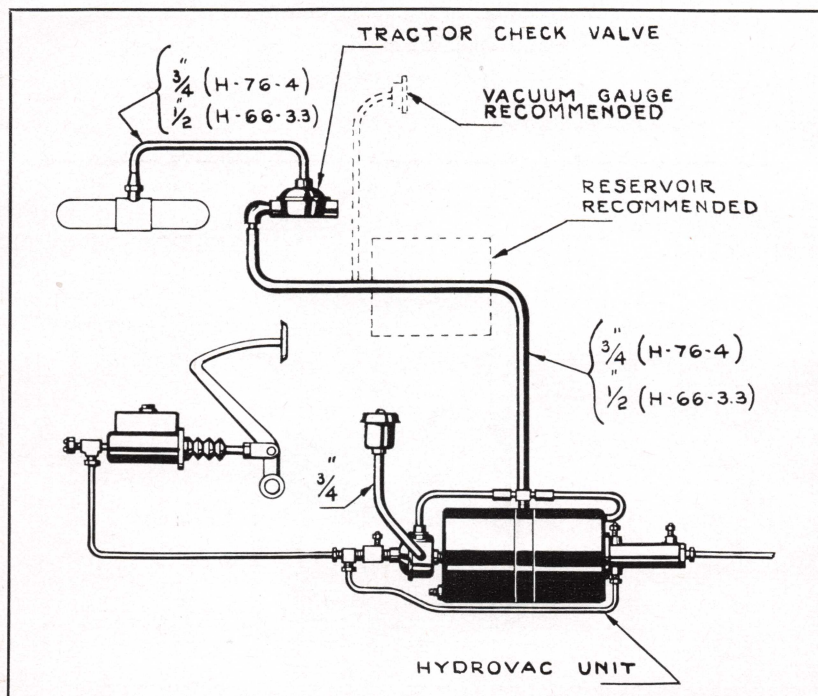
3. Special vacuum suspended truck installation giving both foot and hand control.



4. Vacuum suspended truck installation using internal valve (Reactionary) power cylinder of the puller type.

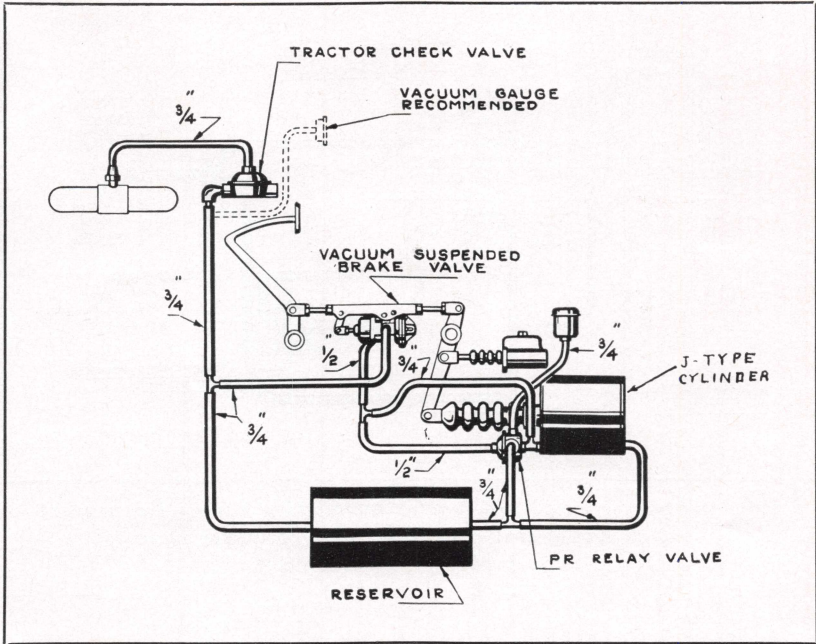


5. Vacuum suspended truck installation using, an internal valve (Reactionary) power cylinder of the pusher type.

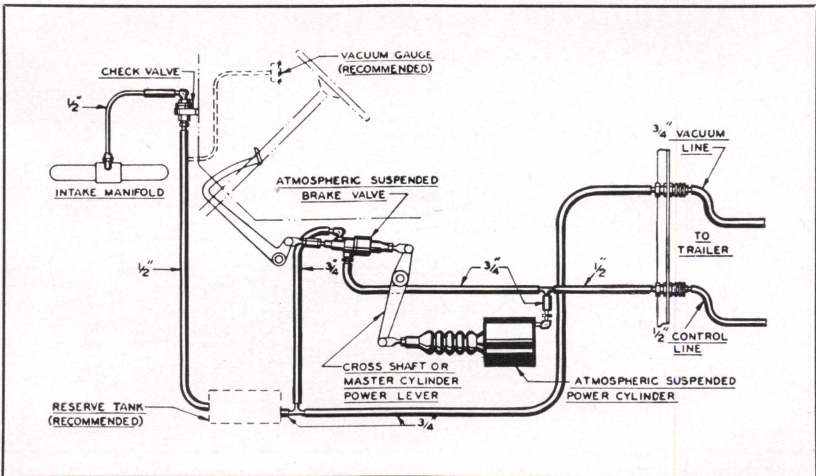


6. Hydrovac installation on a truck. The hydraulic line from the Hydrovac runs to the vehicle wheel cylinders.

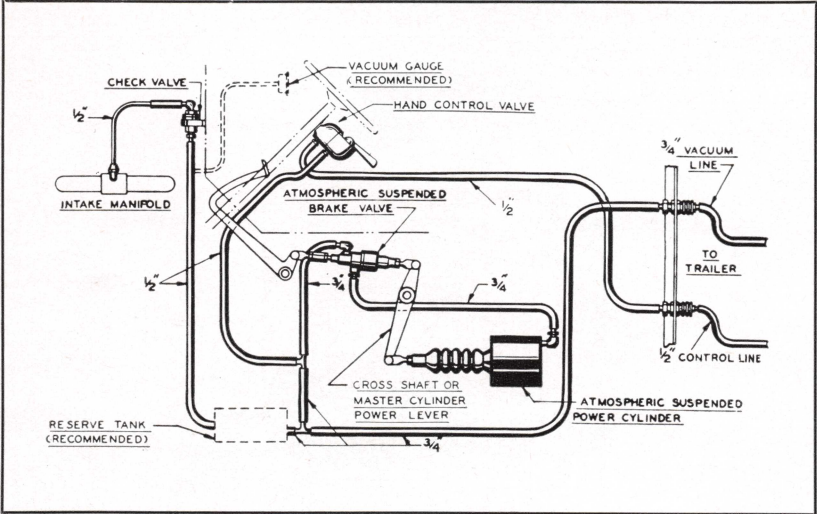
TRACTOR INSTALLATIONS



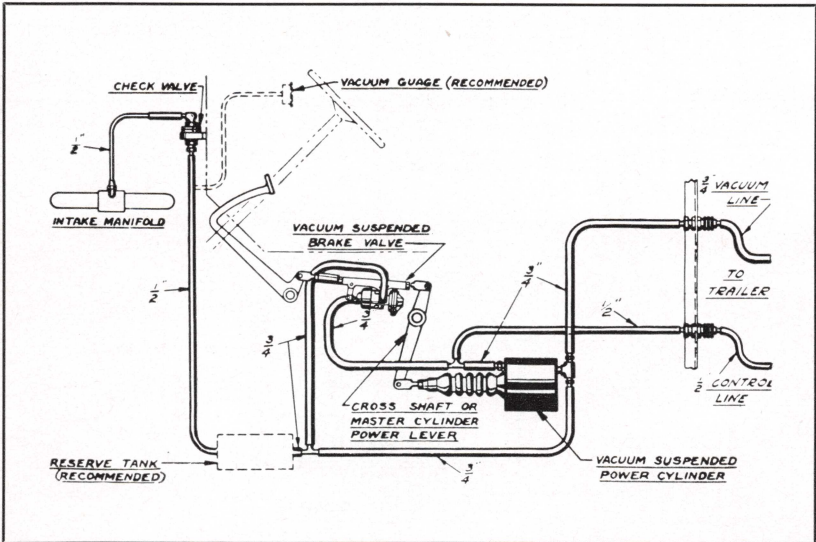
7. Vacuum suspended parallel system for large, heavy duty trucks.
Note use of a relay valve at the power cylinder.



8. Atmospheric suspended tractor installation.

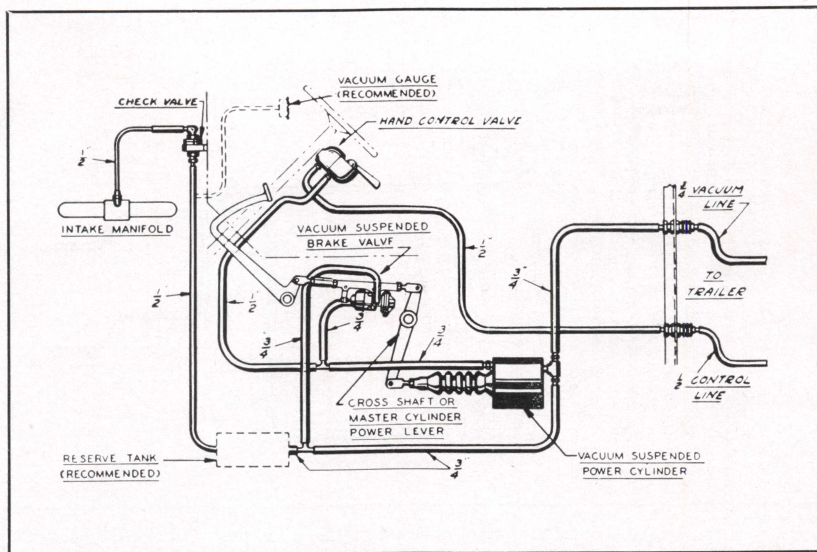


9. Atmospheric suspended tractor installation having independent hand control of trailer brakes. The foot pedal operates the brakes on both vehicles.

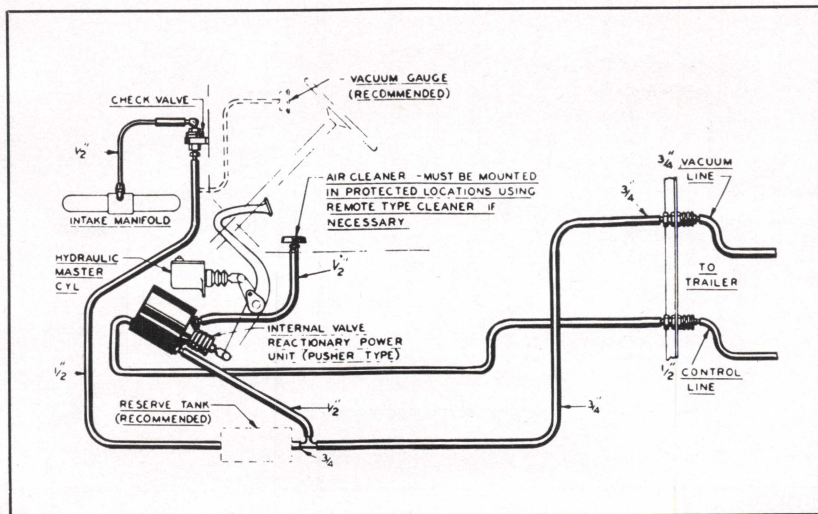


10. Vacuum suspended tractor installation; RXL Reactionary Control Valve shown.

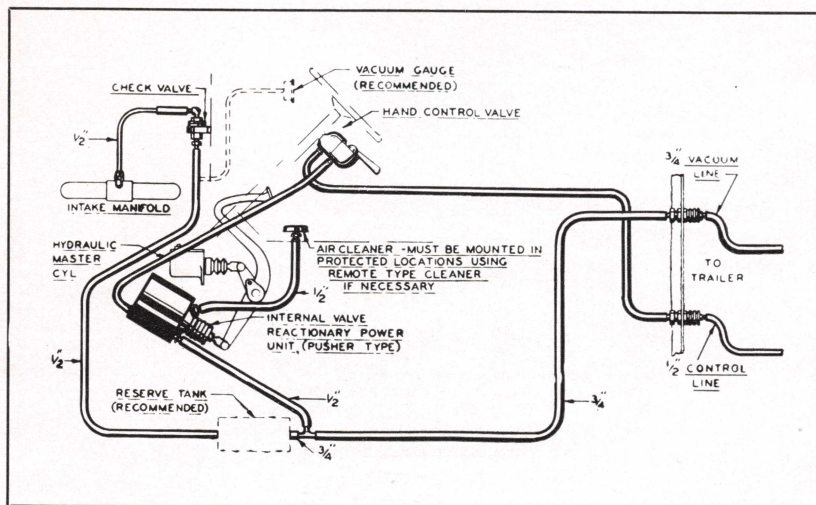
TYPICAL B-K INSTALLATIONS



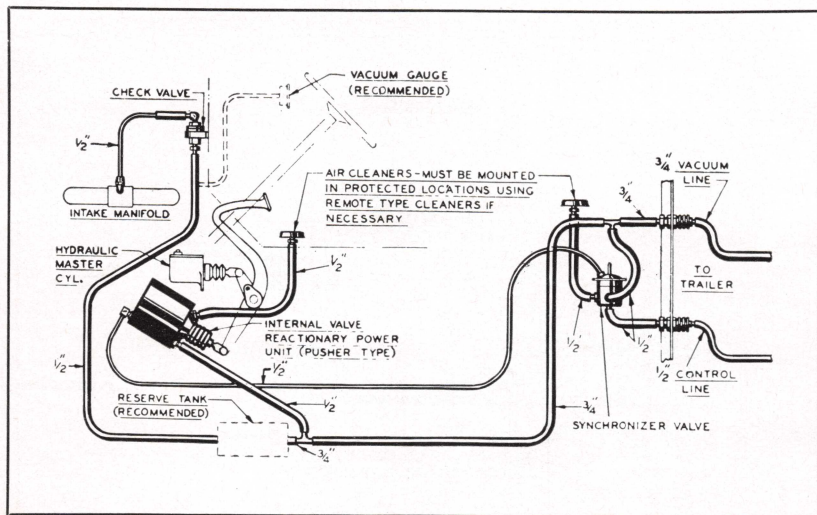
11. Vacuum suspended tractor installation having independent hand control of trailer brakes. The foot pedal operates the brakes on both vehicles.



12. Vacuum suspended tractor installation using an internal valve (Reactionary) power cylinder of the pusher type.

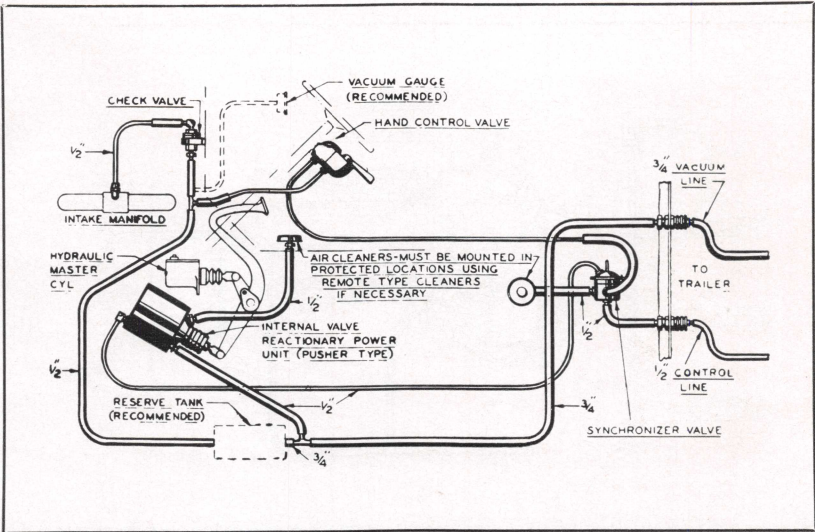


13. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder: the hand valve gives independent hand control of trailer brakes; the foot pedal operates the brakes on both vehicles.

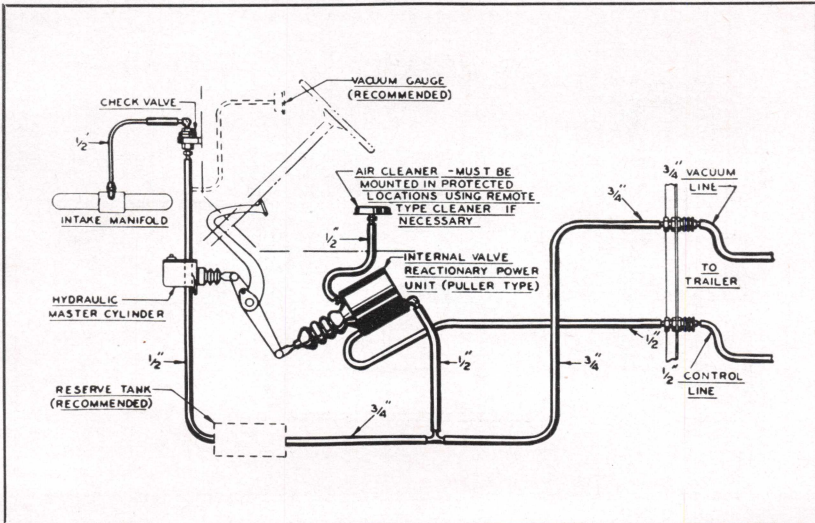


14. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder and Synchronizer Valve. (See page 87).

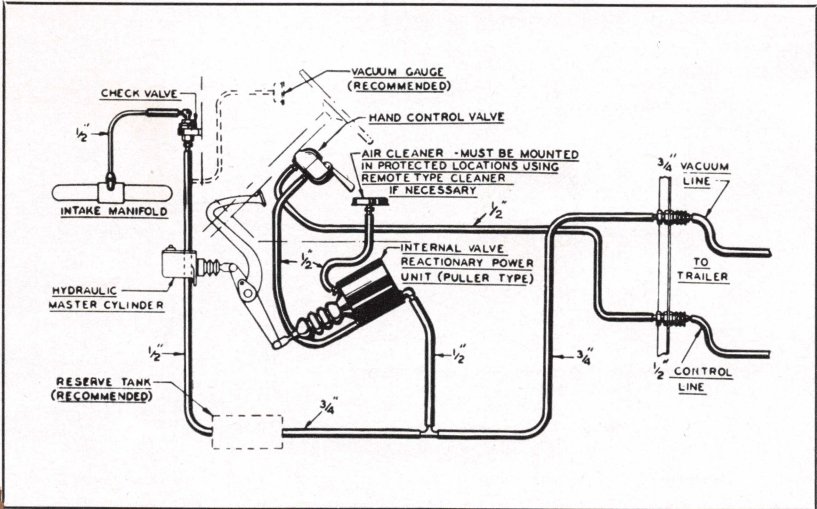
TYPICAL B-K INSTALLATIONS



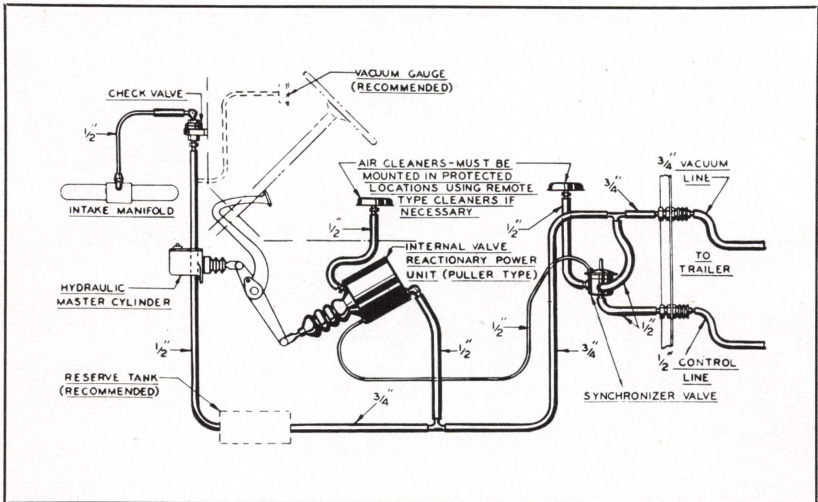
15. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder and Synchronizer Valve (see page 87). The hand valve gives independent hand control of trailer brakes; the foot pedal operates the brakes on both vehicles.



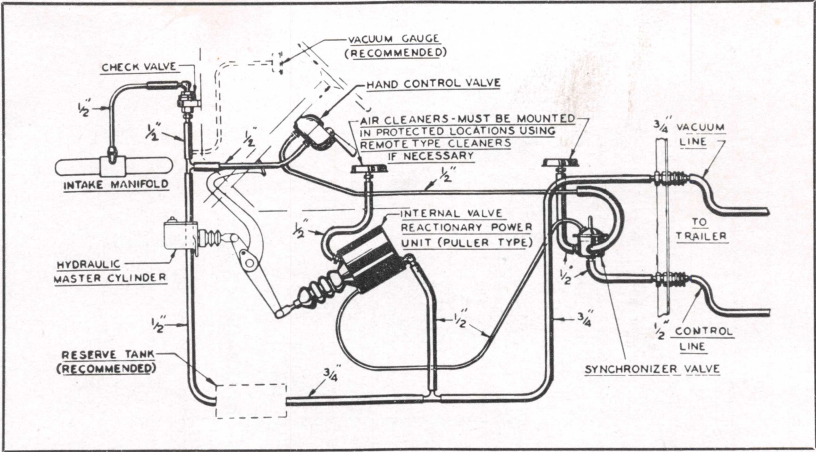
16. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder of puller type.



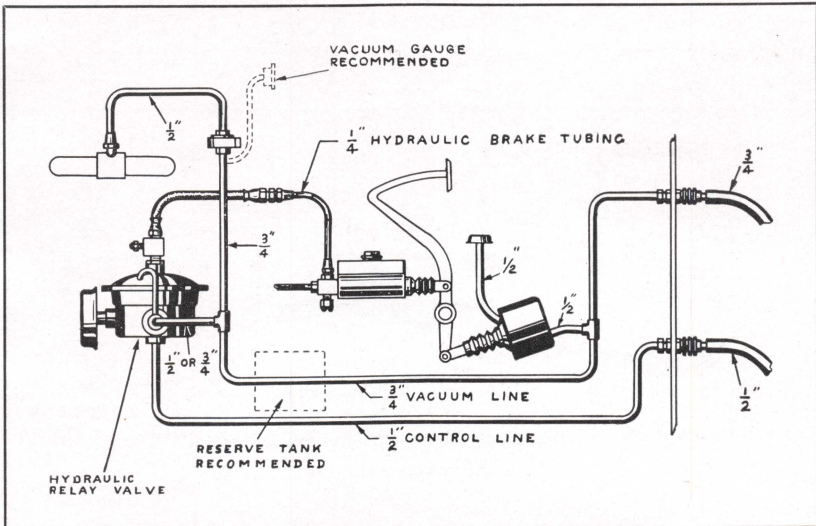
17. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder of puller type: the hand valve gives independent hand control of trailer brakes; the foot pedal operates the brakes of both vehicles.



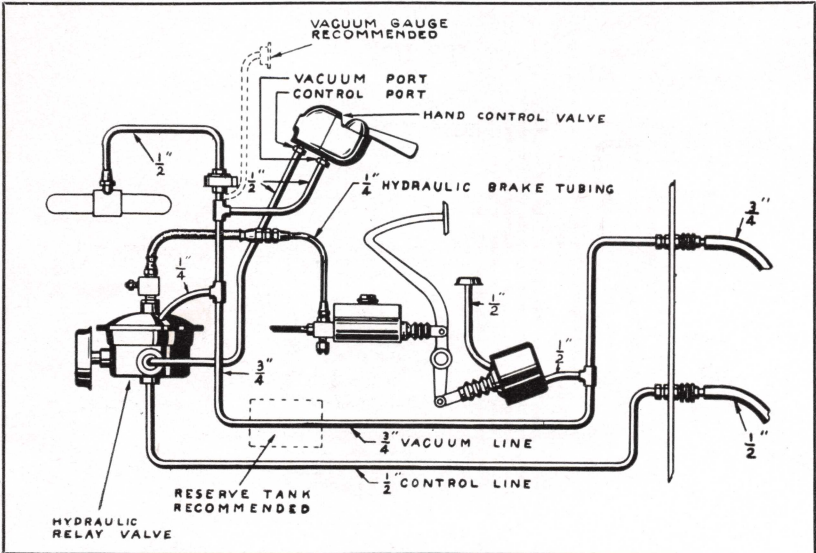
18. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder of the puller type and Synchronizer Valve (see page 87).



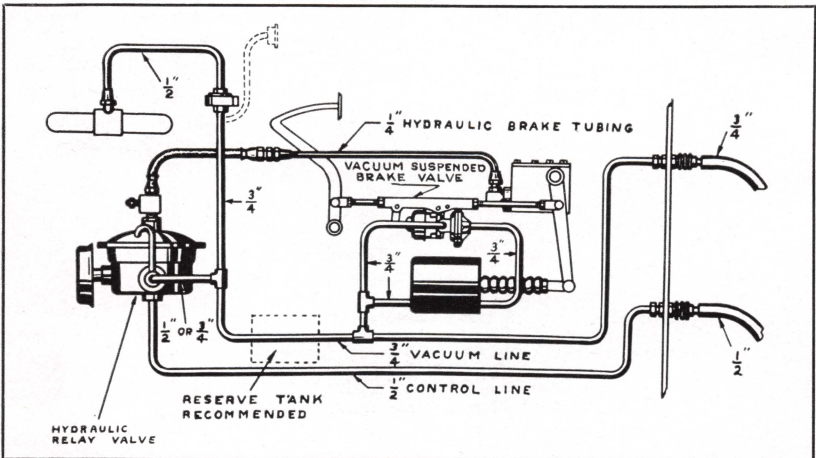
19. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder and Synchronizer Valve (see page 87). The hand valve gives independent hand control of trailer brakes; the foot pedal controls the brakes of both vehicles.



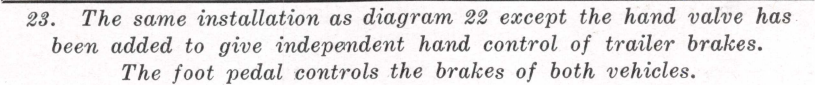
20. Vacuum suspended tractor system using internal valve (Reactionary) power cylinder. The Hydraulic Relay operates directly from the tractor hydraulic line to control the trailer brakes.



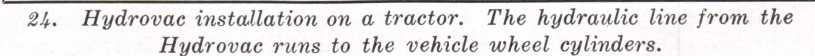
21. Vacuum suspended tractor installation using internal valve (Reactionary) power cylinder. The Hydraulic Relay operates directly from the tractor hydraulic line to control the trailer brakes. The hand valve gives independent hand control of trailer brakes. The foot pedal operates the brakes of both vehicles.



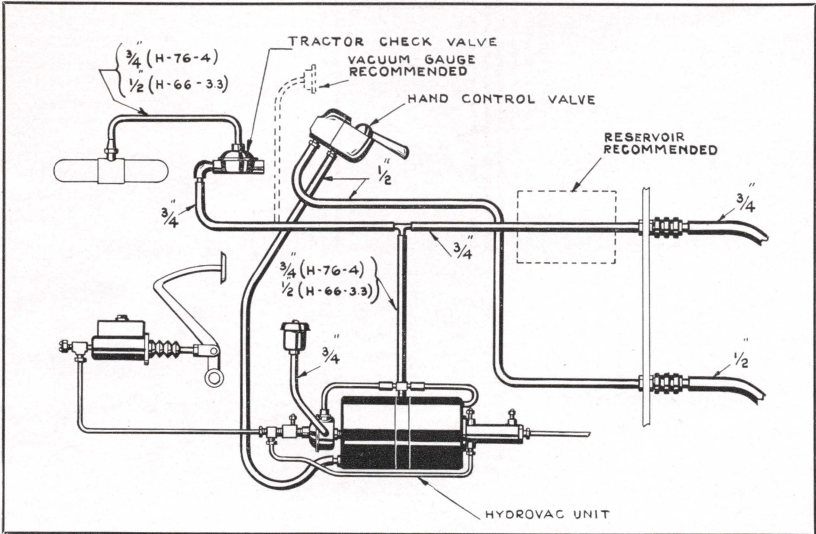
22. Vacuum suspended tractor system using a puller type power cylinder and RXL Valve. The Hydraulic Relay operates directly from the tractor hydraulic line to control the trailer brakes.



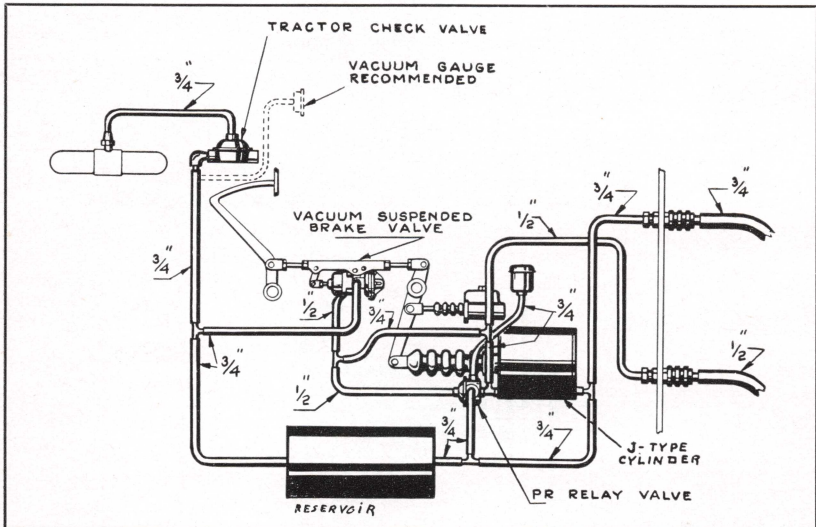
The foot pedal controls the brakes of both vehicles.



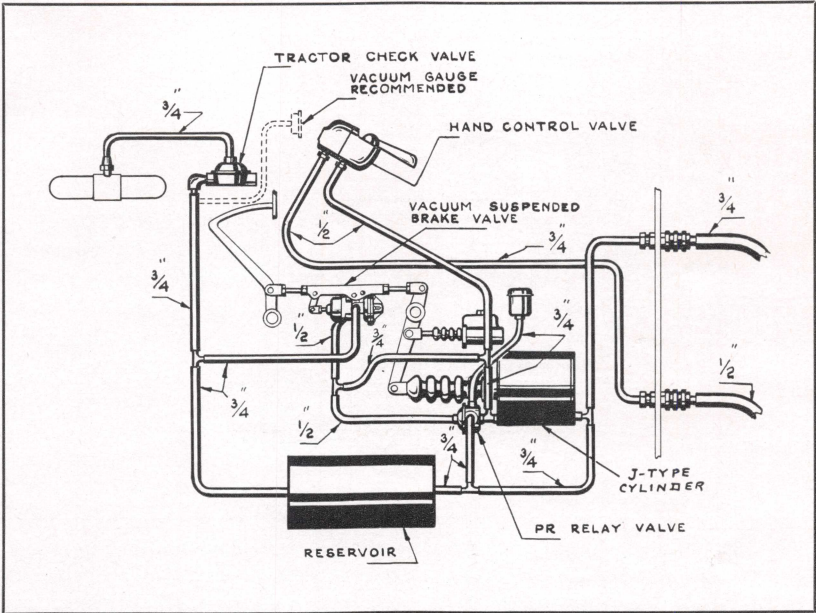
Hydrovac runs to the vehicle wheel cylinders.



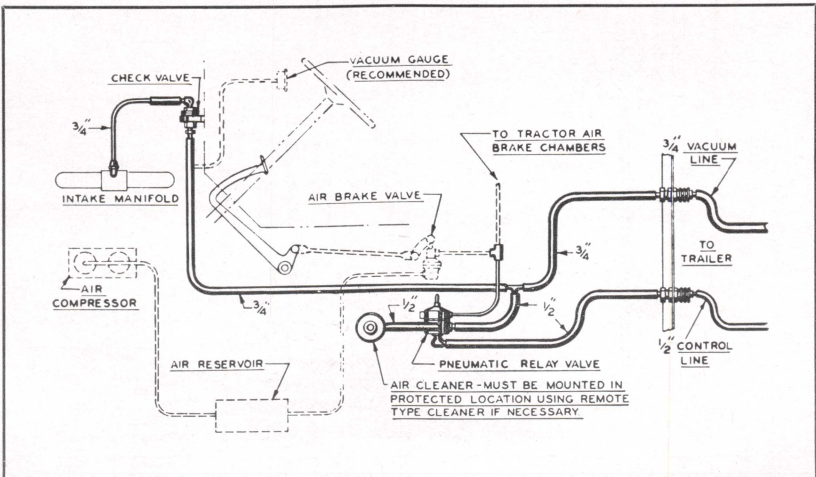
25. *Hydrovac installation on a tractor with hand control valve added to give independent hand control of trailer brakes. The foot pedal controls the brakes on both vehicles.*



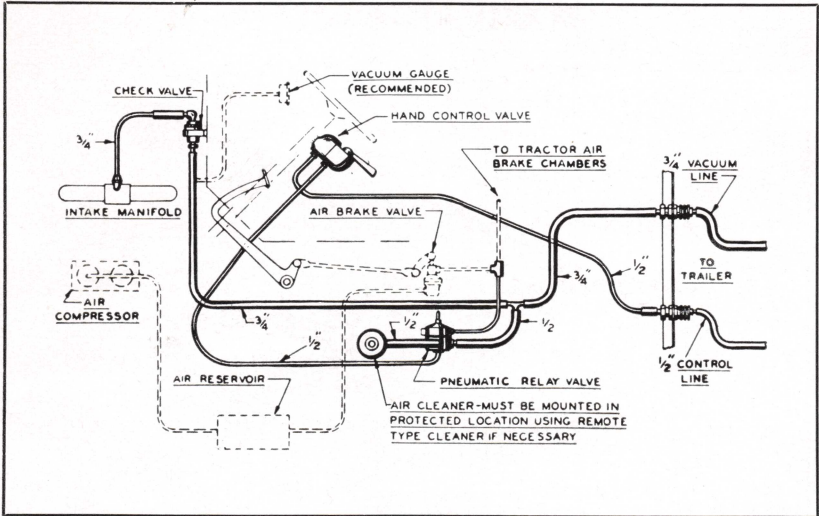
26. Vacuum suspended parallel system for large, heavy-duty trucks and tractors. Note use of relay at the power cylinder.



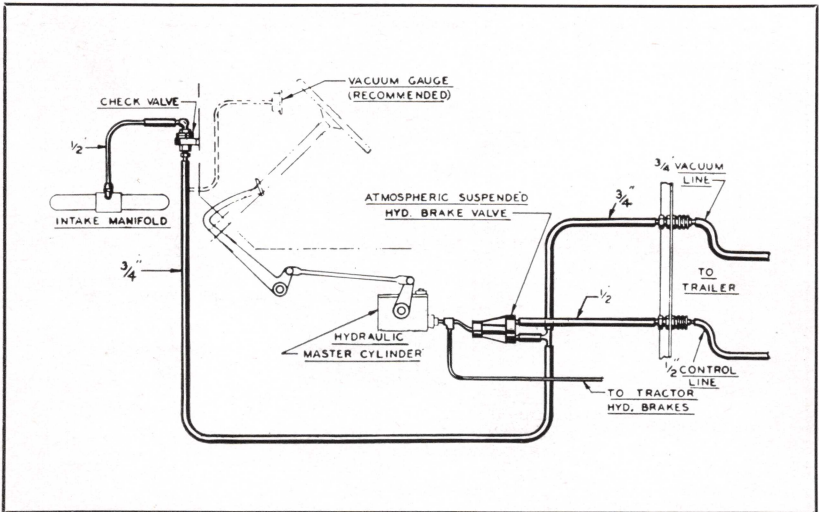
27. Parallel system the same as diagram 26 except the hand valve has been added to give independent hand control of trailer brakes.



28. Tractor equipped with air brakes, but with Pneumatic Relay installation to control a vacuum brake system on the trailer.

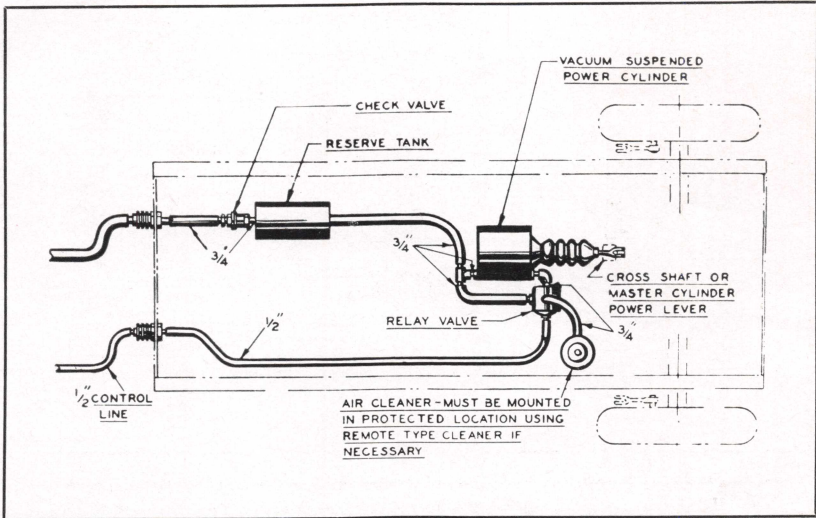


29. Tractor equipped with air brakes, but with Pneumatic Relay installation to control a vacuum brake system on the trailer. The hand valve gives independent hand control of the trailer brakes.

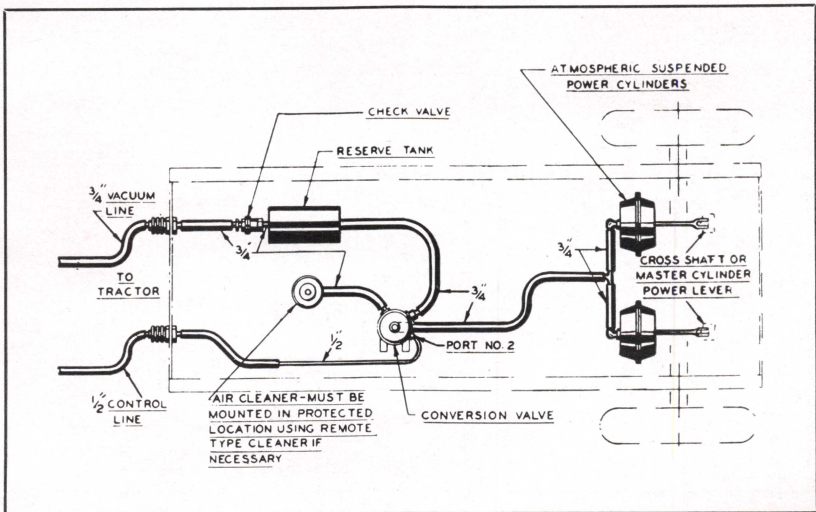


30. An early type installation (no longer recommended). Tractor without power brakes using HVP Valve to control vacuum trailer system (see HVP Valve, page 106).

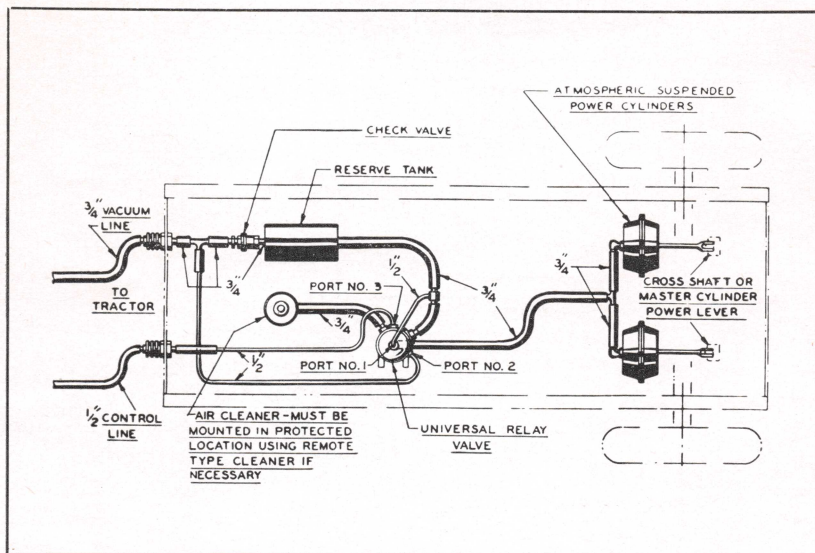
TRAILER INSTALLATIONS



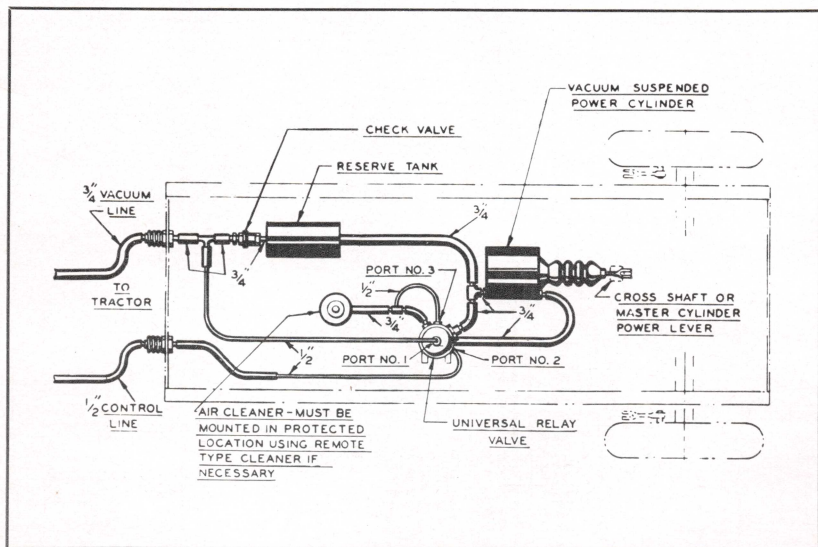
31. Vacuum suspended trailer installation using the PR Relay Valve. Operates from vacuum suspended tractor.



32. Atmospheric suspended trailer installation using the Conversion Valve. Operates from vacuum suspended tractor.

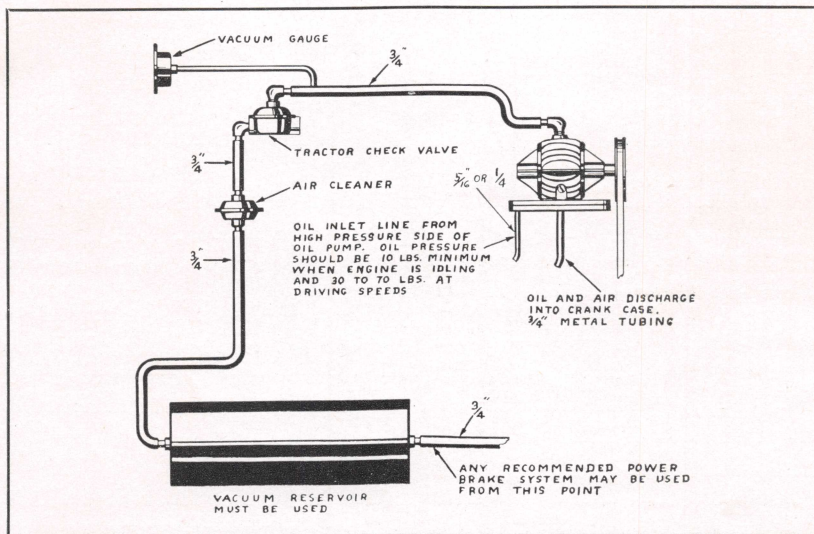


33. Atmospheric suspended trailer installation using the Universal Relay installed to operate from an atmospheric suspended tractor.

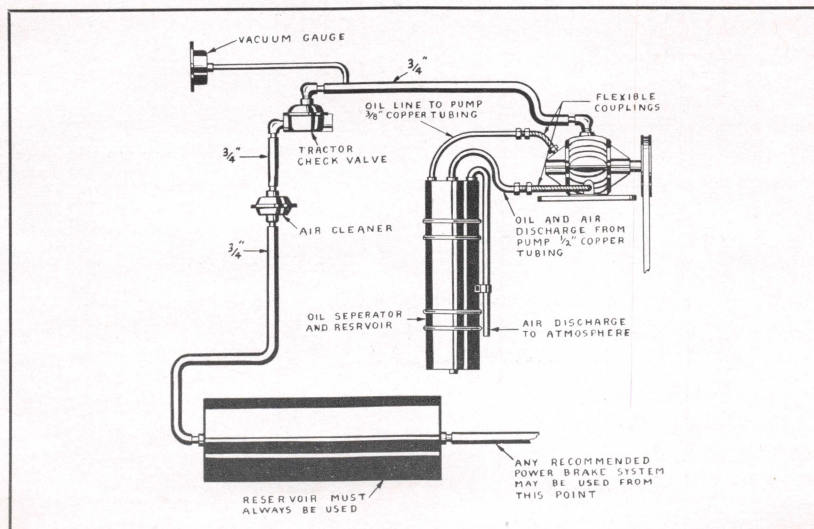


34. Vacuum suspended trailer installation using the Universal Relay installed to operate from an atmospheric suspended tractor.

VACUUM PUMP INSTALLATIONS



35. Convac pump installed for lubrication from the engine pressure lubrication system.



36. Convac pump installed for lubrication from an independent oil supply.

INDEX

	Page		Page
Air cleaners.....	40	Diagrams, Typical B-K Installa- tions.....	109
Air pressure, The moving force...	8	Diaphragm type power units.....	67
AP Control Valve.....	105	Dickson, James T.....	14
Atmospheric pressure.....	1	Discovery of atmospheric pressure	1
Atmospheric suspended system for trucks.....	41	Dissimilar systems, Connecting...	62
Atmospheric suspended system, principles.....	16	DN Power Cylinder.....	105
Automatic brake application....	57, 60	"Double-Line" and "Single-Line"	51
Barometers.....	2	Fisher and Allison.....	19
Bendix, The move to.....	28	Follow-up principle.....	19
BEV Control Valve.....	106	Follow-up valve, Principles of operation.....	46
B-K Vacuum Hose.....	102	Gauge, Vacuum.....	39
BNS Power Cylinder.....	105	Hand control of trailer brakes....	53
"Boosters".....	102	Harnessing "Vacuum Power"....	11
Bragg and Kliesrath.....	20	HB Hand Control Valve.....	106
Break-away feature.....	57	History, Early B-K.....	13
Cartridge Air Cleaner.....	40	Hose couplings.....	52
Check valve.....	36	HVP Control Valve.....	106
Check valve, Power.....	37	Hydraulic Relay.....	89
Check valve, Power, PT.....	59	Hydrovac.....	92
Check valve, Trailer.....	58	Inch-pound rating of power units.	64
Clamp-ring diaphragm.....	69	Installation diagrams.....	109
Compounding.....	64	Installation kits.....	104
Connecting, dissimilar tractor and trailer systems.....	62	Internal valve cylinders.....	66, 72
Control valve, atmospheric sus- pended.....	33	Jumper lines.....	51
Control valve, Location of.....	21	Kliesrath and Bragg.....	20
Control valve vacuum suspended, Operation of.....	42	Leverage.....	64
Convac Vacuum Pump.....	96	Manifold, Connections to.....	31
Conversion Relay.....	63, 80	Manifold vacuum.....	8
Couplings, Hose.....	52	MB Power Cylinder.....	105
Cylinders, Direct-pull rating....	64	Measuring vacuum.....	5
Cylinders, Internal valve.....	28	Operating valve, first type.....	18
D-84 and D-96 diaphragm type power units.....	69	Patent, Dickson.....	18

INDEX (Continued)

	Page		Page
Patent, Root.....	20	Stopper plugs.....	53
Perrier's experiment.....	3	Straddle springs.....	107
PH Hand Control Valve.....	106	Super-X Control Valve.....	49, 50
Plain check valve.....	36	Synchronizer Valve.....	87
Pneumatic Relay.....	91		
Poppet valve reactionary cylinders	76	TC and VC Check Valves (old style).....	107
Power brakes vs. "Boosters".....	102	TC Check Valve.....	58
Power check valve.....	37	Torricelli's experiment.....	1
Power emergency check valve, PT	59	Tractor installation diagrams....	113
Power cylinder, Atmospheric sus- pended.....	32	Tractor system.....	51
Power cylinder, vacuum suspended	44	Trailer emergency check valve...	58
Power of cylinders.....	64	Trailer installation diagrams....	125
Power of vacuum.....	12	Trailer system, Atmospheric sus- pended.....	60
Power unit installations.....	65	Trailer system, Vacuum suspended	56
Power units.....	64	Trailer valve (relays).....	56
PR Relay.....	63, 77	Truck installation diagrams.....	110
Present-Day B-K.....	30	Truck system, atmospheric sus- pended.....	30, 41
PT Power Check Valve.....	59	Truck system, vacuum suspended	42
Pushers, Pullers.....	66		
Q Control Valve.....	105	Universal Relay.....	63, 82
Reactionary control.....	70		
Reactionary control, Advantages of.....	26	VA Control Valve.....	105
Reactionary control, Invention of	25	VAC Regulating Valve.....	107
Reactionary cylinders.....	66, 72	Vacuum and atmospheric pressure	1
Reactionary linkage.....	75	Vacuum cylinder experiment.....	6
Reactionary principle.....	73	Vacuum gauge.....	39
Relays.....	56, 77	Vacuum hose.....	100
Relays for various combinations of systems.....	63	Vacuum pump installation dia- grams.....	127
Relay valves used on tractors....	87	Vacuum reservoir.....	38
Remote air cleaner.....	40	Vacuum suspended system for trucks.....	42
Reservoir.....	38	Vacuum suspended system, In- vention of.....	23
REV Relay Valve.....	107	VC and TC Check Valves (old style).....	107
RH Hand Control Valve.....	54	VC Check Valve.....	36
Root, H. C.....	19		
RXL Valve.....	70	XT-1/2 Valve, Principles of opera- tion.....	46, 49
"Single-Line" and "Double-Line"	51		
Shut-off valves.....	53		

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NOTES

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NOTES

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slightly textured appearance and some minor discoloration or staining, particularly towards the edges. There is no handwriting or other markings on the page.

